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The above and below ground relationships of alfalfa-grass mixtures

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THE ABOVE AND BELOW GROUND RELATIONSHIPS OF ALFALFA-GRASS MIXTURES

by

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TABLE OF CONTENTS

Table of Contents (Continued)

Table of Contents (Continued)

INTRODUCTION

In recent years, alfalfa has become an important forage crop in the southeastern United States. Most alfalfa is seeded in pure stands throughout this region. Mixtures with grasses have not been evaluated. Several alfalfa and grass mixtures have shown some promise, but little is known concerning the behavior of these mixtures over a period of years under hay or grazing conditions.

Whether planted for pasture or hay, there are several recognized advantages of seeding grasses with alfalfa. Under many conditions there is a distinct advantage of the mixture over alfalfa alone in preventing soil erosion. Other advantages generally observed are better control of weeds, less danger of bloat when grazed, and quicker drying of hay in the swath.

Alfalfa has shown excellent potentialities when used for grazing in combination with grasses throughout many regions of the United States, and it would appear that we could obtain much higher pasture forage in the southeastern states by increased use of alfalfa-grass mixtures. The interrelationships of alfalfa and grasses have not been investigated intensively in this area. We need to determine the most desirable alfalfa-grass mixture to use in this region as regards yield, longevity of stand and chemical composition.

Difficulty has been encountered in obtaining a desirable stand of both components in a mixture in preliminary tests throughout North Carolina. In order to obtain an initial survival of both components, as well as maintain a desirable balance, it seems necessary that we develop a better method of seeding the species in mixtures.

Even though rainfall is relatively high in North Carolina, water frequently becomes the limiting factor in the growth of alfalfa. Preliminary observations showed that alfalfa roots, on clay loams, penetrated to maximum depths of three or four feet. There is not sufficient water in this horizon of soil to provide uniform growth of alfalfa during temporary droughts.

Some farmers are presently irrigating pastures and forage crops in the Southeast. If we are to intelligently irrigate forage crops, we must determine their water requirements.

In the experiments reported herein two alfalfa-grass mixtures which have shown promise in North Carolina were studied under several methods and rates of seeding. Differences in seasonal growth of the individual species and nitrogen contents were determined. In one experiment which included only alfalfa and orchard grass, a detailed study was made of the above ground associational effects by partitioning the root systems. The removal of moisture by alfalfa and orchard grass in the different soil horizons was closely followed throughout the growing season by use of Bouyoucos moisture blocks.

The objectives of these experiments were to determine the most desirable grass species to be grown in combination with alfalfa, and the best method of establishment and maintenance of these mixtures. Also, a study was made to determine some of the effects of above ground and below ground associations of alfalfa and orchard grass with the below ground emphasis on moisture usage.

REVIEW OF LITERATURE

Agronomic Value and Adaptation of Grass-Legume Mixtures

According to Ahlgren (2), regardless of the seeding mixture used for pasture, Kentucky bluegrass eventually becomes the dominant species on fertile, upland soils, in almost all portions of the north-central region of the United States. In pasture investigations in Wisconsin, Ahlgren _et al_ (3) obtained results which indicated that production of permanent pastures can be moderately and profitably increased through use of alfalfa, established by renovation.

Sprague and Hein (61) reported that in the northeastern states increased use is being made of alfalfa and bromegrass, and alfalfa and orchard grass for hay and silage followed by aftermath grazing. According to Westover (70), in the corn belt timothy and bromegrass are commonly sown with alfalfa.

Equal or slightly superior yields of alfalfa-grass mixtures compared to alfalfa alone have been reported from widely distributed sections of the United States and Canada (5) (22) (42) (55) (65) (69) (70) (72). Davies (17) noted that in Great Britain the drawback of mono-plantings of lucerne was the cost of keeping them weed-free. Mixtures of cocksfoot with lucerne performed satisfactorily.

Experiments in South Dakota (24) have demonstrated that a mixture of alfalfa and bromegrass was usually more productive the first three years than was alfalfa alone. In the following years bromegrass suppressed alfalfa and lower yields were obtained.

Fundamental Interrelationships of Grass-Legume Mixtures

Rates and methods of seeding

According to Willard (71), the recommended rates of seeding are dependent upon methods of seeding. Methods of seeding entail not only seedbed preparation, but the manner in which the seed are distributed throughout the soil as regards depth and spacing. Willard (71) further claimed that neither drilling nor broadcasting as such affected the most favorable rate of seeding. He presented five years' results from four seedings of Grimm and common alfalfa at rates ranging from 2½ to 50 pounds of seed per acre. There were no significant increases in yield of hay per acre for rates of seeding above 7½ pounds per acre.

In Mississippi (32), no increases in yield were obtained from seeding rates of alfalfa greater than 10 pounds per acre over a four-year period. It was recognized that good seedbed preparation was practiced on experimental plots; therefore they recommended slightly higher rates.

In Cambridge, England (23), lucerne, drilled at a constant seed rate per acre in narrow rows ($3\frac{1}{2}$ and 7 inches), gave a greater yield per acre than when drilled in wide rows ($10\frac{1}{2}$ and 14 inches). Commercial cocksfoot, broadcast in the lucerne seeding at the rate of 10 pounds per acre, produced considerable increase in total yield; this increase occurred principally during the spring months. Harper, in Oklahoma (29), reported that during seasons of severe summer drought, complete failure of sweet clover resulted from narrowly spaced small grain rows. A good stand was obtained from widely spaced rows of small grain. (28)

Competition effects

Evidence was presented by Pavlychenko (47) that underground competition may commence before shading effects are observable. Stahler (63) compared various crops and their ability to compete with bindweed. Alfalfa competed more successfully with bindweed for soil moisture and soil nutrients than any other crop included in this study. Alfalfa was also an excellent competitor for sunlight. Within 20 days after harvest, alfalfa intercepted 95 per cent of the normal sunlight.

In Pennsylvania, an application of heavy rates of nitrogen fertilizer materially decreased the stand of clover on nonirrigated grass-legume sods (54). On irrigated sods with high levels of nitrogen fertilization excellent stands of clover were maintained.

Aberg _et al_ (1) reported one year's results from investigations on the interrelationships between alfalfa, red clover, bromegrass, and timothy. These species were spaced six inches, alternating the species in mixtures both within and between rows. In no case, in either the field or greenhouse study, was there a significant gain or loss in forage or root yields for both members of an association. Significant gains or losses in yield for one crop usually resulted in significant losses or gains, respectively, for the other crop in the association. Response was compensating rather than mutually beneficial or antagonistic. In greenhouse studies, all of the grasses had a significantly higher yield of roots when grown in association with alfalfa and sweet clover, indicating that the fibrous rooted grasses utilized the soil area not occupied by the tap-rooted legumes.

Similar conclusions were reached by Roberts and Olson (51) in experiments with red, alsike, white and sweet clover, and alfalfa, lespedeza, red top and bluegrass. Gains in dry weight and total nitrogen were attributed to wider spacing of the more vigorous component of the mixture, resulting in a more effective use of the plot area.

Extensive investigations at the Wisconsin Station by Wilson (73) have revealed nitrogen excretion occurrences with peas under conditions of fairly low temperatures and long days. He concluded that to obtain excretion there must be sufficient photosynthesis to insure a fairly high rate of nitrogen fixation, but no excess of carbohydrate which ties up the nitrogen as it is fixed. In greenhouse studies, Roberts (52) also obtained increased growth of grasses grown with legumes under long days and cool temperatures. Myers (46) obtained no evidence of excretion of nitrogen by alfalfa grown with bromegrass in sand culture.

The effects of air and soil temperature on growth of several grasses were critically investigated by Brown (11). He reported that the optimum temperature for herbage production and root growth of orchard grass was 70° F., under greenhouse conditions.

Root Distribution

In preliminary investigations in North Carolina (66), one-year old alfalfa roots have been observed at depths of 3½ feet on Cecil clay loams, and 6½ feet on Norfolk clay loams. No further penetration was observed on six-year old stands on similar soils.

In Wisconsin (68) alfalfa roots reached a depth of 7 to 10 feet, whereas in Kansas (44) alfalfa removed water thoroughly to depths of 20 feet. In Ohio (72) alfalfa roots in spring seedings generally reached a depth of 3 or 4 feet in one year.

Burton (13) studied the root distribution and yield of 7 southern grasses, 5 of which were <u>Paspulum</u> species. At the end of one year at least three-fourths of the roots of all the grasses were found in the upper 20 inches of soil. In West Virginia, Gist and Smith (25) found 1246 pounds of orchard grass per acre-inch in the 0-3 inch level, and 29 pounds per acre-inch in the 12-18 inch level.

Botanical Analyses

In comparing the inclined point quadrat method with
percentage
separations, Arny (6) obtained a low per cent of alfalfa and a high per cent of Kentucky bluegrass as compared to hand separations. Sprague and Myers (62), using the inclined point quadrat, found that the estimated percentage of white clover when grown with Kentucky blue grass was lower than that found by botanical separation.

Soil Moisture

<u>General relationships</u>

An extensive literature review of soil moisture in relation to plant growth has been made by Kramer (41).

Haynes (31) studied the effect of availability of soil moisture upon vegetative growth and water use of corn. He found that the quantity of vegetative growth was markedly affected by the degree of availability of soil moisture within the range from near saturation to near the permanent wilting percentage. Davis (19) in studies with nut grass arrived at similar conclusions, as did Scofield (56) in irrigation studies with alfalfa.

Davis (18) showed that roots of established corn plants absorbed water from the soil more rapidly near the plant than at distances of 3 or 4 feet. Hunter and Kelley (34) obtained data with alfalfa and guayule which showed that roots extracted moisture in the topsoil at fairly high tensions while moisture was available at lower tensions in the subsoil. The greatest concentration of roots were present in the upper part of the soil column. In their studies they brought the top 32 inches of a 72-inch soil column to the wilting point, and watered the lower 40 inches. The alfalfa produced some growth, but not nearly as much growth as when the whole column was wet.

Changes in the moisture content of a silt loam soil to a depth of 8 feet were recorded in California (33) from three bare, unprotected plots during a period of 22 months. The total loss of water was 47 per cent of that initially available for plant growth.

Tensions

Kohnke (40) has presented charts relating the range of soil moisture to various energy concepts, including the Bouyoucos block method. Woodruff (74) stated that in most instances the principal supply of water available for plant growth was held between pF 3.0 and pF 4.1. Studies with several Indiana soils (53) further verified this degree of tension at wilting.

Investigations by Richards and Weaver (49) showed that on 102 of 119 soils studied, the permanent wilting percentage was in the range between the 15 atmosphere percentage and 1.5 per cent moisture above that figure. They also studied (50) the relationships between tensions at first permanent wilting percentage and ultimate wilting percentage. The per cent water in an Altamount clay loam was 10.0 per cent at first permanent wilting, and 8.8 per cent at ultimate wilting, on Altamount clay 6.8 and 5.2 per cent.

Browning (12) reported that with sandy soils the field capacity was recognized as being higher than the moisture equivalent; however, the field capacity tended to be lower than the moisture equivalent with clay soils.

Research by Colman (14) indicated that shallow field irrigation, or the irrigation and drainage of short soil columns in the laboratory, will not necessarily provide a valid measure of the field capacity of the soil. His studies in California showed that the soil must be wetted to a depth of 12 to 30 inches before the surface layer will have attained a moisture content as high as normal field capacity. Smith and Browning (59) concluded that lack of thorough wetting may cause the natural field capacity to be equal to or lower than the moisture equivalent.

Ohms resistance

Colman (15) outlined the general specifications for electrical soil moisture meters which express soil moisture tension in ohms resistance. Bouyoucos and Mick (8) reported early investigations with the Bouyoucos blocks in Michigan. The fiberglas, electrical, soil-moisture units which were developed by the California Forest and Range Experiment Station are described in detail by Colman (16). These units are very resistant to weathering and a thermistor for temperature determinations is self-contained in the soil moisture units. Bouyoucos (7) developed a liquid electrical resistance thermometer that can be read by the same bridge as soil moisture. He stated (8) that ordinary variations in temperature in Michigan during the growing season did not seriously affect the block resistances. These electrical soil moisture units are used to indicate freezing and thawing in the soil, and to measure soil moisture tensions. Soil moisture percentages between approximately 1 and 15 atmospheres can be calculated from calibrations.

Kelley (36) described in detail a satisfactory method used in calibrating Bouyoucos blocks. Comparisons were made by Slater and Bryant (58), under field conditions, between the behavior of tensiometers, resistance blocks, and gravimetric plugs. Moisture blocks appeared superior to tensiometers with respect to range of operation. Comparisons of similar methods and thermal units were made by Kelley et al (37) in 1946. They concluded that the Bouyoucos blocks were the most practical instruments available for measuring moisture changes above 1 atmosphere.

In recent investigations with gypsum blocks, Bouyoucos and Mick (9) showed that the critical minimum value of resistance blocks was approximately 600 ohms. Resistance values of 450 to 600 ohms characterized the moisture equivalent for a fairly large number of widely different soil samples. Hunter and Kelley (34) demonstrated that significant variations in the resistance of Bouyoucos blocks occurred when absorption by the root systems lowered the soil moisture to a tension greater than 1 atmosphere.

According to Bouyoucos and Mick (9), an arbitrary resistance of 75,000 ohms has proved practical as an indicator of the maximum forces against which plants can obtain moisture from the soil. They also postulated that a resistance of 1,000,000 ohms may be a better index of the wilting percentage. Their results showed that a small change in the volume of total soil water will give rise to a relatively great resistance change between 75,000 and 1,000,000 ohms. A further significant conclusion of these investigations was that resistance readings may be directly interpreted in terms of available soil water. They indicated that the percentage of available water in all soils was approximately the same for any given resistance value.

Requirements of alfalfa

The significance of subsoil moisture in alfalfa production has been intensively studied by workers in Nebraska (38)(39), and Kansas (20)(26)(27)(44)(45). In Nebraska (39), on land cropped four years to alfalfa, the subsoil moisture was reduced close to the minimum point of exhaustion to a depth of 15 feet. On land that had previously grown alfalfa, even as remotely as 15 years, the yields appeared dependent upon current rainfall, from the very beginning (38). Experiments in Kansas (45) have shown that there is no measurable accumulation of moisture under established alfalfa stands below a depth of about 3 feet.

The water requirements of alfalfa under irrigation have been studied by several workers. In Nebraska (57), over a four-year period, alfalfa yielded 4.88 tons of hay annually per acre from a water input of 48.46 inches. An average of 12.91 inches of this amount was supplied annually by rainfall; the remainder was furnished by irrigation.

In Montana (21), an average seasonal application of 30.72 inches of water, including rainfall, produced an average yield of hay of 4.12 tons per acre. In Oregon (30) comparisons showed that the mean alfalfa yield following application of 118 acre-inches of irrigation water was 15.4 tons per acre, and following 60 acre-inches, 7.7 tons per acre.

From greenhouse studies, Sprague and Graber (60) concluded that deferred cutting of alfalfa greatly increased total water utilization. Briggs and Shantz (10) showed that there was a marked rise in the water requirement of alfalfa during the hot periods of summer. According to Fortier (21), alfalfa roots absorbed approximately 750 tons of water for each ton of hay produced.

MATERIALS AND METHODS

Experiment A. Rate and Method of Seeding Two Alfalfa-Grass Mixtures

The seedings of this experiment were established August 31, 1946, near Raleigh, in the lower Piedmont area of North Carolina. The soil was a Cecil sandy clay loam. It had been planted to small grain-lespedeza during the past five years and to cotton for several years prior to that time.

In late July the land was double disked, and two weeks prior to seeding the land was disked again with a light tandem disk, drag harrowed, fertilized, and raked with a potato hoe.

The individual plots were 4 by 17 feet. All of the plots were uniformly fertilized. The fertilization and treatment variables studied are listed as follows:

1. Fertilization (Base application):

    a. Initial application:

        2000 pounds - Agricultural limestone
        200 pounds - P_2O_5 (18% superphosphate)
        100 pounds - K_2O (62% muriate of potash)
        20 pounds - N (32.5% ammonium nitrate)
        30 pounds - Agricultural borax

b. Annual application

500 pounds - 0-12-12 Borax

100 pounds - Muriate of potash (62% K_2O)

2. Mixtures (Treatment variables):

   a. Alfalfa (Medicago sativa, var. Kansas common) and orchard grass (Dactylis glomerata L.)

   b. Alfalfa (Medicago sativa, var. Kansas common) and tall fescue (Festuca elatior, var. arundinacea - alta)

3. Rates of seeding (Treatment variables):

	Alfalfa pounds per acre	Grass pounds per acre
a.	20	5
b.	20	10
c.	20	15
d.	10	10
e.	15	10

4. Methods of seeding (Treatment variables):

   a. Broadcast. Each species was broadcast uniformly over the plot and covered with a potato hoe.

   b. Mixed in the row. Each plot consisted of 8 rows spaced 6 inches apart. Alfalfa and grass were seeded in a mixture in each of the 8 rows. The rows were opened and covered with a garden plow.

   c. Alternate row. Each plot consisted of 8 rows spaced 6 inches apart. Alfalfa and grass were seeded alternately in the 8 rows.

Tests of germination percentage before planting gave 90 per cent for orchard grass and tall fescue and 80 per cent for alfalfa, the remaining alfalfa being considered hard seed.

A split block design was used for this experiment, the mixtures being the whole plots, the rate of seeding the first split, and the method of seeding the second split.

A general view of the experiment in June, 1947, the first year after seeding, is shown in Figure 1. Also shown are photographs of the broadcast, mixed in the row, and alternate row plots of alfalfa-orchard grass. Equally uniform stands of alfalfa-fescue were obtained.

Yields

The plots were harvested four or five times per season with a Jari cutter bar power mower. The vegetation was cut to a height of two and one-half inches at each cutting. A strip 2 feet wide and 15 feet long was harvested from the center of each plot, dried at 130° F., and weighed after reaching equilibrium with a dry atmosphere. The borders were cut immediately after each harvest, and the forage removed.

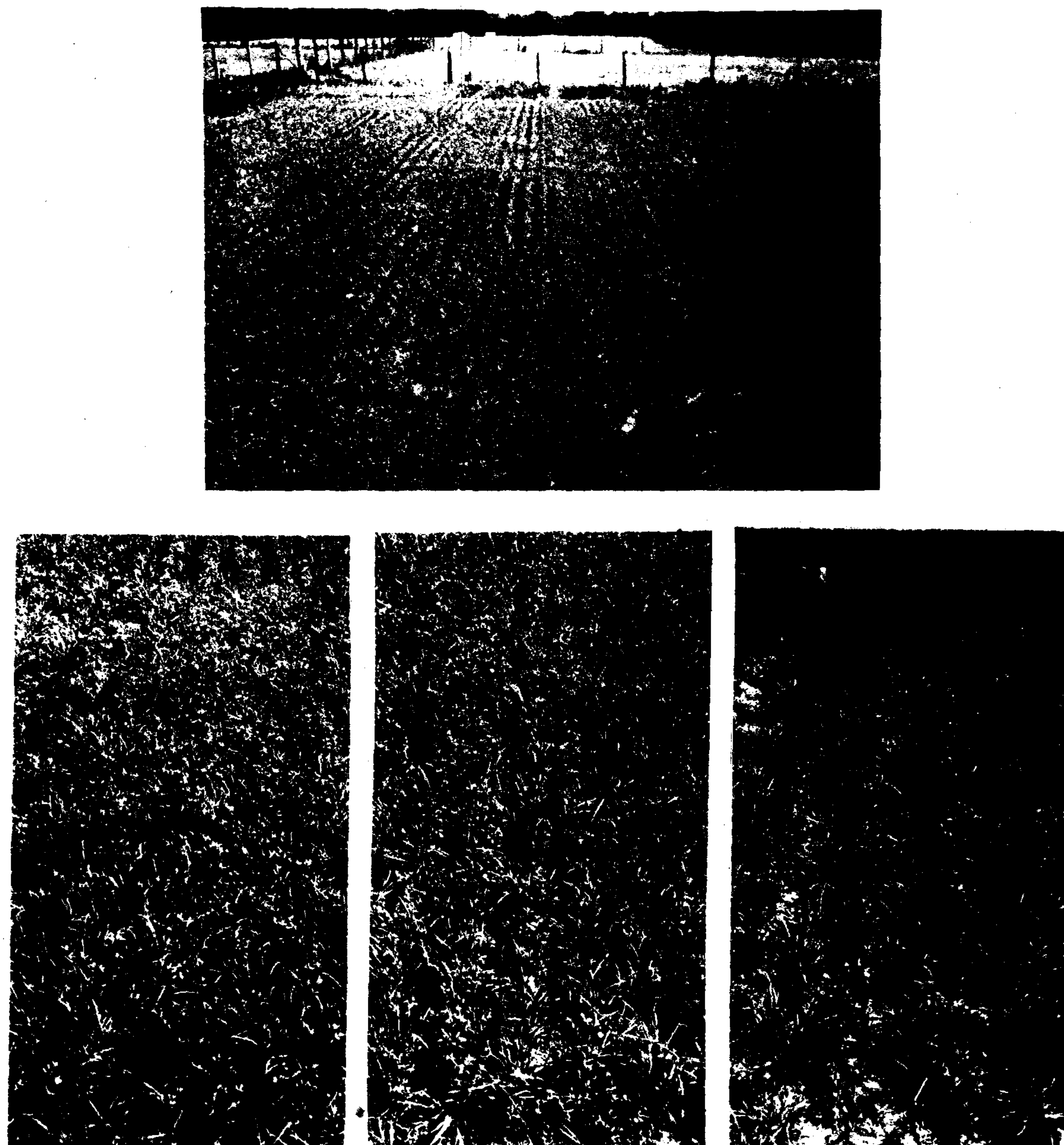

Figure 1. Top: General view of Experiment A.

Bottom: Left. Alfalfa-orchard grass - broadcast.
Center. Alfalfa-orchard grass - mixed in the row.
Right. Alfalfa-orchard grass - alternate row.

Botanical Analyses

Actual stand counts were made on all plots approximately three weeks after seeding by the count list quadrat method. A quadrat 18 inches by 24 inches, subdivided into appropriate subdivisions was employed. Three readings were made per plot.

Botanical analyses were made by hand separations on all plots (90) at the first and third harvests. At the other harvests, only one seeding rate (20 pounds alfalfa-10 pounds grass) was botanically separated. Immediately after harvesting an area 2 feet by 15 feet, the forage was subsampled and the portion used for botanical analyses placed in cold storage. Fifty per cent of the harvested sample was used for botanical separations. The separations were made within 10 days after harvest, and the dry weights recorded.

Chemical Analyses*

Total nitrogen percentages were determined by the A. O. A. C. method on the individual species obtained by botanical separation. The treatments analyzed are shown with the data.

Statistical Analyses

The data were subjected to an analyses of variance, and least significant differences were calculated at both the one

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* Analyses by J. R. Piland, Research Associate Professor of Agronomy, North Carolina Agricultural Experiment Station.

and five per cent levels. In order to demonstrate the method of statistical analyses employed, some complete analyses of variances are presented. In most instances, however, only the least significant differences are reported in this manuscript. These least significant differences are presented only for treatments that were significantly different. If there were no differences between treatments the differences are noted with the data as non-significant (N. S.). All interactions are noted in the presentation of results.

Experiment B. Spacing Study of Two Alfalfa-Grass Mixtures

This experiment was established adjacent to Experiment A and on the same date. The land preparation, fertilization and seeding mixtures were similar. The individual plots were 4 by 17 feet. Treatment variables studied are listed as follows:

1. Mixtures (Treatment variables):
    a. Alfalfa, 20 pounds per acre orchard grass, 10 pounds per acre.
    b. Alfalfa, 20 pounds per acre tall fescue, 10 pounds per acre.
2. Spacings (Treatment variables):
    a. Narrow spacing—alternate rows spaced 6 inches.
    b. Wide spacing—alternate rows spaced 12 inches.

A split block design was used, the mixtures being the whole plots and the spacings the subplots. There were three replications.

The narrow spacing plots were similar to the alternate row plots in Experiment A. They consisted of 8 rows spaced 6 inches apart, with the center 4 rows harvested and saved. The wide spacing plots consisted of 4 rows spaced 12 inches apart, with the center 2 rows harvested. An equal area was harvested from each plot. On a per acre basis the seeding rates under both spacings were similar. The alternate rows were harvested separately in order to obtain the botanical composition of the mixture. Nitrogen contents were determined on the grasses in the mixtures.

The first year after seeding, 1947, the alfalfa-orchard grass was harvested and discarded because of heavy weed infestation. It was saved during the second year.

Experiment C. Root Partition Study of Alfalfa and Orchard Grass

This experiment was designed to study the above and below ground relationships of alfalfa and orchard grass. A study of the above ground effects of these plants was facilitated by installing sheet metal partitions which prevented intermingling of the root systems. Water removal by alfalfa and orchard grass at various soil depths was determined with Bouyoucos soil moisture blocks.

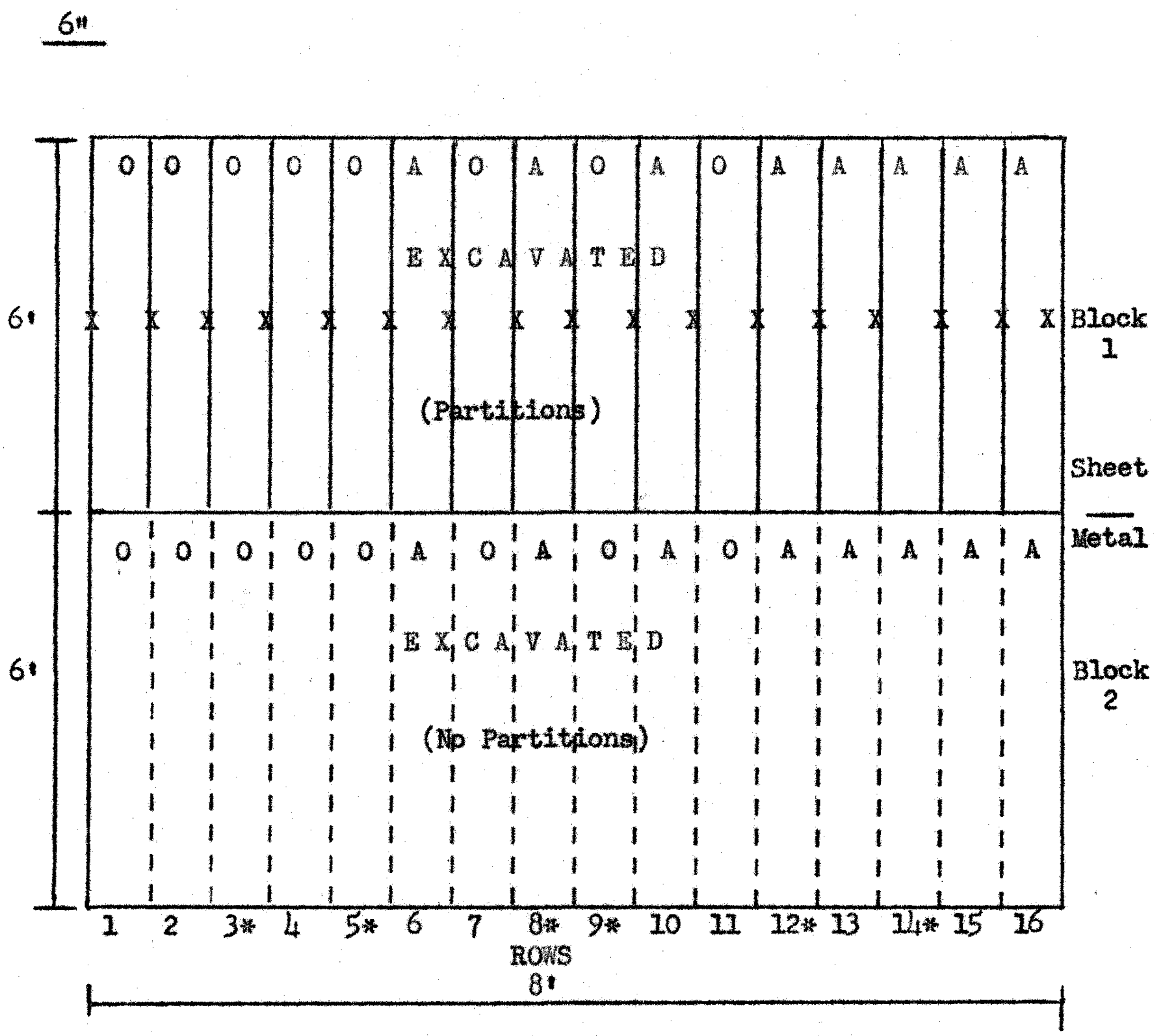
Installation of moisture blocks and sheet metal partitions was completed one month prior to seeding on September 1, 1947. The experiment was established adjacent to Experiments A and B. Various combinations of alfalfa and orchard grass growing in rows spaced 6 inches were studied, with and without partitioned root systems. The principal treatments are listed as follows:

1. Orchard grass row - orchard grass rows adjacent. O-O-O.
2. Orchard grass row - alfalfa rows adjacent. A-O-A.
3. Orchard grass row - orchard grass row and alfalfa row adjacent. O-O-A.
4. Alfalfa row - alfalfa rows adjacent. A-A-A.
5. Alfalfa row - orchard grass rows adjacent. O-A-O.
6. Alfalfa row - alfalfa row and orchard grass row adjacent. A-A-O.

These treatments and their arrangement are noted in Figure 2 which shows a diagrammatic view of one replication.

As shown in Figure 2, each replication consisted of 16 rows of alfalfa and orchard grass in various combinations. Each individual row was 12 feet long, with each row spaced 6 inches from adjacent rows. Six feet of each row had underground sheet metal partitions separating it from

Figure 2. A diagrammatic top view of one replication of Experiment C.



X = Underground sheet metal partitions extending downward 30 inches

O = Row of orchard grass.

A = Row of alfalfa.

* = Principal treatments studied.

adjacent rows; the remaining 6 feet were not partitioned. A split block design was used, the alfalfa-grass combination being the whole plots, and the partitioned and nonpartitioned treatments the subplots. There were five replications. The treatments were not completely randomized; however, the order of treatments was reversed in the various replications. Since the soil was thoroughly mixed in each replication, complete randomization of treatments was not considered necessary. If the treatments had been completely randomized, several additional border rows would have been required.

The soil was excavated to a depth of 30 inches. Each replication was handled separately, and the soil was removed in layers of six inches. Before replacing the soil, asphalted sheet metal partitions 6 feet by 30 inches were placed vertically 6 inches apart in one-half of the excavated area of each replication (Figure 3). As shown in Figure 3, Bouyoucos moisture blocks were placed at various levels under the principal treatments as the soil was replaced. The soil was replaced in 6 layers in its original position.

Ten paired pieces of 3/16" by 3/4" flat bar mild steel, 36 inches in length were welded to a piece of 3/8" by 1" flat bar mild steel, 6 feet in length. This steel frame was used to hold the sheet metal rigid during replacement of the soil in its original position (Figure 3). The lower ends of the "clasps" were pushed tightly together by placing 2 by 6 inch

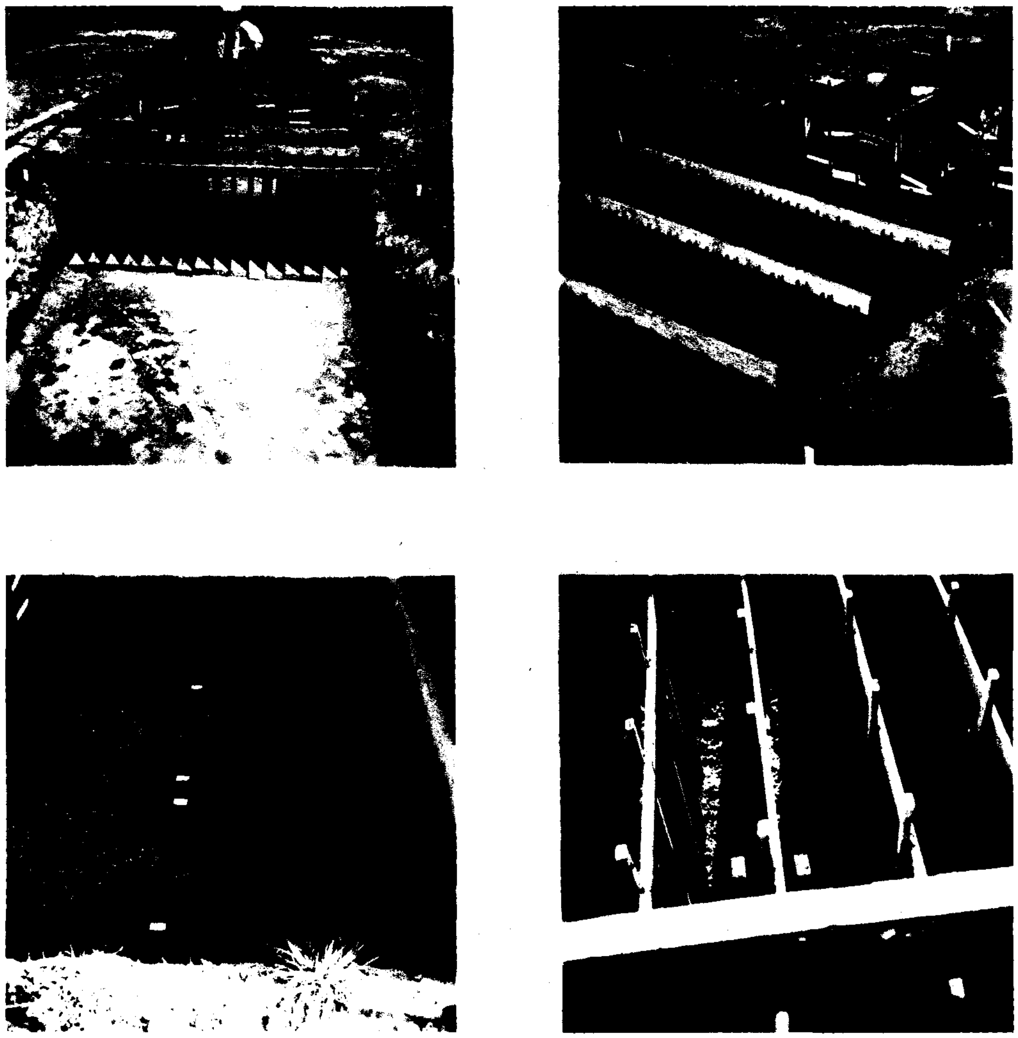


Figure 3. Top: Sheet metal partitions in place for one replication.

Bottom: Placement of Bouyoucos' moisture blocks at 24-inch depth.

lumber, which was 6 feet in length, in the bottom of the hole (Figure 3). The lower ends of the "clasps" were driven into the ground by tapping the upper ends with a heavy hammer. The boards were then removed and the soil was replaced in the hole. After the completion of one replication, the steel frames were removed from the hole, and used again in the next replication. Seventeen of these frames were required, as noted in Figure 3.

This experiment was fertilized similarly to Experiments A and B.

Yields

Each individual row, including border rows, was harvested separately with electric shears and dried at 130° F. There were 160 individual rows, 32 per replication (Figure 2). Four harvests were made in 1948.

Soil moisture

In the five replications, Bouyoucos gypsum blocks were placed at depths of 3, 6, 12 and 24 inches under rows 3, 8, 9, and 14 in the partitioned section. In the nonpartitioned section additional blocks were placed at 30 inches under rows 3 and 14 and to a depth of only 12 inches under rows 8 and 9 (Figure 2).

A total of 140 gypsum blocks were installed. Resistance readings were made with a Bouyoucos ear phone bridge approximately every other day from April 21 through September 20, 1948, except during an extreme drought from June 21 to July 16. During this period the blocks were too dry to obtain accurate readings.

The initial operation of excavation and the establishment with alfalfa and orchard grass are shown in Figure 4.

Rainfall measurements were taken adjacent to the experiment during the course of this investigation. These data are reported in Table 1 of the Appendix.

Chemical analyses

Nitrogen contents were determined on the forage obtained from rows 3, 5, 8, 9, and 14 (Figure 2).

Statistical analyses

Analyses of variance were computed on yield of forage from rows 3, 5, and 9 of orchard grass, with a separate analyses on rows 8, 12 and 14 of alfalfa (Figure 2).

Laboratory determinations

Calibrations of per cent moisture were determined for each horizon of soil in which gypsum blocks were placed in Experiment C. The procedures outlined by Kelley (36) were followed.

Figure 4. Top: Initial operation of excavation of Experiment C.

Bottom: Establishment of alfalfa and orchard grass.

Samples of soil were collected during excavation from the 0-6, 6-12, 12-18, 18-24, and 24-30 inch layers in each replication. The replications were composited, and the calibrations were computed on the composited samples for each depth.

Duplicate samples from each layer of soil were used in the determinations of ohms resistance versus per cent moisture. The soil with the block centrally imbedded was wet by capillarity. It was dried and wet again before the readings were begun. Colman (16) suggested that a more stable structure can be attained in this manner.

After the completion of one cycle of taking resistance readings and weights as the soil dried, the soil was saturated and the experiment repeated.

In a calibration of this type, it is necessary to subtract the water in the block at any given resistance. Each block used in the calibrations was wet by capillarity and its weight at various resistances was recorded. Recent investigations (64) have shown that inaccurate results are obtained unless the blocks are wet by capillarity. The relationships between resistance in ohms and per cent moisture, in the various horizons, are presented in Figure 1 (Appendix).

Resistances in ohms were obtained in the field with the ear phone Bouyoucos bridge. The relationship between ohms resistance and per cent moisture tends to be logarithmic; consequently, each resistance reading for each replication was converted to per cent moisture, and then an average per cent moisture for the five replications calculated. The resistance in ohms that this average per cent moisture represented was determined for each horizon of soil from the resistance versus per cent moisture curves obtained for each horizon of soil (Figure 1 of the Appendix).

In Tables 2 and 3 of the Appendix, data in ohms resistance, based on an average of the five replications, are presented for all dates on which readings were made. In Tables 4 and 5 of the Appendix, the data in per cent moisture are presented for all dates on which readings were made. All data shown in Tables 2 and 3 of the Appendix, are simply an expression in ohms resistance of the data in Tables 4 and 5 (Appendix) given in per cent moisture. These resistance values were obtained from Figure 1 (Appendix) which shows the per cent moisture versus resistance in ohms relationships for the various horizons of soil.

The permanent wilting percentages of each horizon of soil were biologically determined as described by Loomis and Schull (43). Corn seedlings were subjected to severe wilting when reaching a height of approximately 18 inches. Duplicate determinations were made for each layer of soil.

EXPERIMENTAL RESULTS

Experiment A

Yields

The seasonal yields of two alfalfa-grass mixtures, as influenced by rate and method of seeding, were determined. In the spring of 1947 there was a deficiency of rainfall in May, whereas June was an extremely dry month in 1948 (Table 1). In Tables 2 and 3, the seasonal and total yields are presented for 1947 and 1948.

Combined analyses of all cuttings in 1947 showed that the only significant treatment differences were between rates of seeding. As the rate of seeding of grass with 20 pounds of alfalfa was increased from 5 to 15 pounds, the average yield of alfalfa-orchard and alfalfa-fescue decreased from 7806 pounds to 6936 pounds of forage per acre. Also the yield was less the first year when only 10 pounds of alfalfa was used with 10 pounds of grass.

No differences in total yields were obtained in 1947, at the first three harvests, between methods of seeding; however, at the last two harvests there were differences between methods.

TABLE 1. Monthly and semimonthly distribution of rainfall at Raleigh, North Carolina.(1947 and 1948).

	1947	1948	60-Year Average
April 1-15	2.10	2.23	
16-30	.98	.12	
Total	3.08	2.35	3.52
May 1-15	.21	1.64	
16-31	1.90	1.59	
Total	2.11	3.23	3.95
June 1-15	2.80	1.80	
16-30	1.87	.47	
Total	4.67	2.27	4.46
July 1-15	4.28	1.71	
16-31	1.52	3.96	
Total	5.80	5.67	5.79
Aug. 1-15	2.23	4.28	
16-31	2.96	1.13	
Total	5.19	5.41	5.42
Sept. 1-15	3.72	.61	
16-30	8.81	3.40	
Total	12.53	4.01	3.84

TABLE 2. Seasonal yields in pounds dry matter per acre as influenced by rate and method of seeding. (1947).

Experiment A

Rate Alfalfa-Grass	Method	Alfalfa-Orchard grass May 8	June 16	July 21	Aug. 25	Oct. 8	Total
	Alternate	1946	530	1851	1824	1202	7353
20-5	Broadcast	2039	704	1880	2103	1474	8198
	Mixed	2101	721	1898	2123	1398	8241
Average		2029	652	1876	2017	1358	7932
	Alternate	2221	634	2027	1893	1083	7858
20-10	B roadcast	2089	702	1892	1929	1381	7993
	Mixed	2010	707	1883	2005	1291	7896
Average		2107	681	1934	1942	1252	7916
	Alternate	1685	486	1561	1544	942	6218
20-15	Broadcast	1796	604	1675	1974	1280	7329
	Mixed	1704	588	1704	1812	1358	7166
Average		1728	559	1647	1777	1193	6904
	Alternate	1870	625	1907	1794	1062	7258
10-10	Broadcast	1666	526	1500	1686	1189	6567
	Mixed	1789	614	1659	1804	1198	7064
Average		1775	588	1689	1761	1150	6963
	Alternate	1849	692	1834	1779	1153	7307
15-10	Broadcast	2006	731	1692	1982	1374	7785
	Mixed	1844	676	1783	1856	1381	7540
Average		1900	700	1770	1872	1303	7545
Grand average	Alternate	1914	593	1836	1767	1088	7198
	Broadcast	1919	653	1728	1935	1340	7575
	Mixed	1890	661	1785	1920	1325	7581

L.S.D. Between:							
Mixtures	(.05)	N.S.	N.S.	N.S.	N.S.	N.S.	N.S.
	(.01)						
Rates*	(.05)	180	N.S.	N.S.	167	140	659
	(.01)	249			230	199	908
Method*	(.05)	N.S.	N.S.	N.S.	97	76	N.S.
	(.01)				129	102	
C.V.		13	15	9	10	11	8

*Must average the two mixtures to apply the above L.S.D.'s.

TABLE 2 (Continued).

Rate Alfalfa-Grass	Method	Alfalfa-Tall fescue May 8	June 16	July 21	Aug. 25	Oct. 8	Total
20-5	Alternate	1844	636	1693	1682	1393	7248
	Broadcast	1972	736	1740	1994	1654	8096
	Mixed	2021	664	1737	1843	1429	7694
Average		1946	679	1723	1840	1492	7680
20-10	Alternate	1994	568	1662	1873	1362	7459
	Broadcast	2085	726	1832	1957	1464	8064
	Mixed	1935	585	1498	1788	1530	7336
Average		2005	626	1664	1873	1452	7620
20-15	Alternate	1986	602	1724	1660	1306	7278
	Broadcast	1731	570	1607	1729	1258	6895
	Mixed	1768	554	1518	1668	1226	6734
Average		1828	575	1616	1686	1263	6968
10-10	Alternate	1866	569	1611	1713	1324	7083
	Broadcast	1681	595	1591	1752	1350	6969
	Mixed	1578	500	1329	1545	1250	6202
Average		1708	555	1510	1670	1308	6751
15-10	Alternate	1777	559	1690	1594	1260	6880
	Broadcast	1695	605	1588	1677	1233	6798
	Mixed	1893	717	1618	1774	1418	7420
Average		1788	627	1632	1682	1304	7033
Grand average	Alternate	1893	587	1676	1704	1329	7189
	Broadcast	1833	646	1672	1822	1392	7365
	Mixed	1839	604	1540	1724	1371	7078

TABLE 3. Seasonal yields in pounds dry matter per acre as influenced by rate and method of seeding. (1948).

Experiment A

Rate Alf.-Grass	Method*	Alfalfa-Orchard grass Apr. 28	June 8	Aug. 4	Sept. 9	Total	Alfalfa-Tall fescue Apr. 28	June 8	Aug. 4	Sept. 9	Total
20-5	A	2042	1405	1248	1242	5937	2043	1406	1210	1189	5848
	B	2207	1583	1364	1382	6536	2479	1601	1338	1260	6678
	M	2220	1653	1304	1343	6520	2181	1439	1273	1181	6074
	Average	2157	1547	1305	1322	6331	2235	1482	1274	1210	6201
20-10	A	2331	1516	1317	1120	6284	2287	1401	1257	1036	5981
	B	2210	1611	1381	1152	6354	2299	1595	1362	1208	6464
	M	2262	1568	1398	1227	6455	2152	1514	1341	1161	6168
	Average	2268	1565	1365	1167	6365	2245	1504	1320	1135	6204
20-15	A	1720	1299	1144	1038	5201	1953	1505	1191	1157	5806
	B	2178	1467	1218	1142	6005	2021	1580	1232	1114	5947
	M	2017	1436	1355	1222	6030	1900	1439	1239	1094	5672
	Average	1972	1401	1239	1134	5764	1959	1508	1221	1121	5809
10-10	A	2150	1472	1331	1143	6096	2031	1320	1267	1065	5683
	B	1877	1396	1197	1077	5547	2221	1461	1250	1069	6001
	M	2033	1493	1293	1005	5824	1896	1275	1050	887	5108
	Average	2020	1454	1274	1075	5823	2049	1352	1192	1007	5600
15-10	A	1901	1462	1208	1198	5769	1884	1422	1230	1154	5690
	B	2274	1683	1246	1255	6458	2173	1520	1304	1157	6154
	M	2086	1512	1319	1238	6155	2422	1531	1296	1178	6427
	Average	2087	1552	1258	1230	6127	2160	1491	1277	1163	6091
Grand average	A	2029	1431	1249	1148	5857	2040	1411	1233	1120	5804
	B	2149	1548	1281	1201	6179	2239	1551	1297	1162	6249
	M	2124	1532	1334	1207	6197	2110	1439	1240	1100	5889

L.S.D. Between:

Mixt.	(.05)	N.S.	N.S.	N.S.	N.S.	N.S.
	(.01)					
Rates**	(.05)	N.S.	N.S.	N.S.	N.S.	N.S.
	(.01)					
Meth.**	(.05)	107	67			226
	(.01)	146	89	N.S.	N.S.	302
C.V.		10	9	10	11	7

*A = alternate rows, B = broadcast, and M = mixed in the row.

**Must average the two mixtures to apply above L.S.D.'s.

As noted in Table 2, the alternate row plots yielded less than either of the other two methods at the fourth harvest. At the fifth harvest there was an interaction between mixtures and methods of seeding. The alternate row plots of alfalfa and fescue yielded as well as the other methods.

During this period of the season orchard grass was not contributing much growth in the mixture. The wide spacing of alfalfa in the alternate rows was probably not optimum spacing for maximum growth of alfalfa. Tall fescue was growing vigorously in the early fall and contributed its proportionate part to the total growth of the mixtures. Excellent growth of tall fescue was obtained in alternate row spacings, and by the second season this aggressiveness led to less total yields.

In the second year, 1948, combined analyses of all cuttings showed differences only between methods of seeding. In Table 3 the yields are given for all cuttings. Statistical analyses of individual harvests and of total yields for the season showed that there were no interactions between treatments. The average total yield of all alternate row plots was 5830 pounds of forage compared to 6214 pounds in the broadcast plots.

Differences in methods of seeding were evident at the first two harvests in 1948. The alternate row plots produced less forage than the broadcast or mixed in the row plots. No significant differences in rates of seeding were evident at any harvest in the second year.

The average annual yields of all treatments for the two-year period are presented in Table 4. An average of all methods and rates of seeding showed no difference in total yield between alfalfa-orchard grass and alfalfa-tall fescue. A combined analyses (Table 5) of the two years showed no difference, at the five per cent level of probability, between rates of seeding; however, the differences were large enough to closely approach significance at the five per cent level.

There were nine cuttings made over the two-year period. As the stand became older, rate of seeding had less influence on total yield and method of seeding had a more pronounced effect. The mixed in the row plots of alfalfa-fescue tended to produce less forage than the broadcast plots, though the differences were not significant.

Botanical Analyses

Seedling counts were made three weeks after seeding. The results are reported in Table 6. The data showed that seedlings were present three weeks after seeding in proportion to the rate of seeding under all methods.

The number of alfalfa seedlings present per square yard was not affected in this experiment by method of seeding. The number of grass seedlings initially established was affected by

TABLE 4. Total yields as influenced by rate and method of seeding.

(Average annual yield 1947 and 1948).

Experiment A

Rate Alfalfa-Grass	Method	Pounds of dry matter per acre		
		Alfalfa-Orchard grass	Alfalfa-Tall fescue	Average
	Alternate	6646	6548	6597
20-5	Broadcast	7368	7387	7377
	Mixed	7381	6884	7132
Average		7131	6940	7035
	Alternate	7071	6720	6895
20-10	Broadcast	7174	7264	7219
	Mixed	7176	6751	6963
Average		7140	6911	7026
	Alternate	5709	6542	6125
20-15	Broadcast	6666	6421	6544
	Mixed	6598	6203	6400
Average		6324	6389	6357
	Alternate	6677	6387	6532
10-10	Broadcast	6057	6485	6271
	Mixed	6444	5655	6050
Average		6393	6176	6284
	Alternate	6538	6286	6412
15-10	Broadcast	7122	6476	6799
	Mixed	6847	6924	6885
Average		6835	6562	6699
Grand	Alternate	6528	6497	6512
average	Broadcast	6877	6807	6842
	Mixed	6889	6483	6686
Average		6765	6596	6680

L.S.D. Between:

Mixtures (.05)	N.S.
Rates (.05)	N.S.
Methods (.05)	256
C.V.	5

TABLE 5. Combined analyses of variance of yield of dry matter in pounds per acre (1947 and 1948)

Experiment A

Source of variation	Degrees of freedom		Mean Square
Whole plots		5	
Replications	2		10,707,755
Mixtures	1		2,579,793 N.S.
Error (a)	2		5,787,491
Split plots		24	
Rates	4		9,136,802 N.S.
Rate x Mixt.	4		323,126 N.S.
Error (b)	16		3,616,685
Split-split plots		60	
Methods	2		3,262,784*
Meth. x rates	8		1,317,167 N.S.
Meth. x mixt.	2		1,269,221 N.S.
Meth. x rates x mixt.	8		1,339,901 N.S.
Error (c)	40		965,250
Total		89	

Least Significant Difference Between Methods (.05) 256

Coefficient of Variation 7%

TABLE 6. Plant population counts three weeks following seeding as influenced by rate and method of seeding. (September 1946).

Experiment A

Rate Alfalfa-Grass	Method*	Number of seedlings present per square yard								
		Alf.-Orchard grass			Alf.-Tall fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
20-5	A	410	176	586	400	113	513	406	145	551
	B	379	138	517	369	78	447	374	108	482
	M	407	219	626	483	99	582	445	159	604
Average		399	178	577	418	97	515	408	137	545
20-10	A	383	367	750	423	186	609	403	277	680
	B	413	303	716	458	180	638	436	241	677
	M	444	411	855	494	166	660	469	289	758
Average		413	360	773	459	177	636	436	269	705
20-15	A	398	503	901	359	296	655	379	400	779
	B	398	409	807	476	275	751	437	342	779
	M	467	540	1007	377	286	663	422	413	835
Average		421	484	905	404	286	690	413	385	798
10-10	A	254	381	635	244	219	463	249	300	549
	B	206	369	575	258	203	460	232	286	518
	M	228	428	656	254	219	473	241	323	564
Average		230	393	623	252	214	466	241	303	544
15-10	A	314	399	713	314	188	502	314	293	607
	B	326	274	600	306	181	487	316	228	544
	M	374	437	811	343	226	569	359	331	690
Average		338	370	708	321	198	519	330	284	614
Grand average	A	352	365	717	348	201	549	350	283	633
	B	344	299	643	374	183	557	358	241	599
	M	384	407	791	390	199	589	387	303	690

L.S.D. Between:		Alf.	Grass	Total
Mixtures**	(.05)	N.S.	47	N.S.
	(.01)		107	N.S.
Rates	(.05)	51	43	55
	(.01)	71	59	76
Methods	(.05)	N.S.	28	98
	(.01)		37	131

*A = alternate rows, B = broadcast, and M = mixed in the row.

**Must average the three methods for orchard and the three for fescue to apply this significant L.S.D.

method of seeding. A better initial establishment of orchard grass was obtained by mixed in the row and alternate methods than by broadcast seeding. Tall fescue showed no difference, with the particular environmental conditions, between methods. Deeper covering probably was obtained by mixed in the row and alternate row than by the broadcast method. Probably more grass seedlings were produced by any of the methods than would survive under competition for any great length of time.

Botanical separations of all treatments were made at the first and third harvests in both years. At the other harvests only one seeding rate was separated. The data obtained in 1947 are summarized in Tables 7, 8 and 9.

On May 8, 1947, an average of 400 grams per plot of alfalfa were obtained from the broadcast plots, whereas 371 and 354 grams of forage were obtained from the mixed in the row and alternate row plots, respectively. Similar relationships were shown at the July 21 harvest. The grass responded inversely. Tall fescue was more favored by alternate seeding than was orchard grass. A combined statistical analyses of the above two harvests further verified the above relationships.

At both the first and third harvests less alfalfa was present in plots which had received a high seeding rate of grass or less than 15 pounds of alfalfa. Analyses on individual species at the two harvests did not show a significant difference in yield; however, there was significant difference in total yield between

TABLE 7. Botanical analyses as influenced by rate and method of seeding. (May 8, 1947).

Experiment A

Rate Alfalfa-Grass	Method*	Average grams dry weight of individual species per plot								
		Alf.-Orchard grass			Alf.-Tall fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
20-5	A	353	122	475	360	136	496	356	129	486
	B	418	162	580	411	150	561	414	156	570
	M	420	169	589	401	135	536	411	152	563
Average		397	151	548	391	140	531	394	146	540
20-10	A	390	167	557	365	182	547	377	174	551
	B	433	137	570	419	176	595	426	157	583
	M	425	135	560	335	209	544	380	172	552
Average		416	146	562	373	189	562	394	168	562
20-15	A	332	55	387	317	247	564	325	151	476
	B	396	103	499	357	143	500	376	123	500
	M	345	119	465	322	177	499	334	148	482
Average		358	92	450	332	189	521	345	141	486
10-10	A	362	101	464	340	201	541	351	151	502
	B	331	70	401	362	133	495	347	101	448
	M	385	105	489	251	161	412	318	133	451
Average		359	92	451	318	165	483	338	128	467
15-10	A	389	70	459	329	131	460	359	101	460
	B	475	91	566	396	90	486	436	91	526
	M	416	106	522	413	145	558	414	126	540
Average		426	89	515	380	122	502	403	106	509
Grand average	A	365	103	468	342	180	522	354	141	495
	B	411	113	524	389	138	527	400	126	525
	M	398	127	525	344	165	509	371	146	517

L.S.D. Between:

		Alf.	Grass	Total
Mixtures	(.05)	N.S.	N.S.	N.S.
	(.01)			
Rates	(.05)	N.S.	N.S.	57
	(.01)			79
Methods	(.05)	25	N.S.	N.S.
	(.01)	33		
C.V.		13	38	16

*A = alternate rows, B = broadcast, and M = mixed in the row.

TABLE 8. Botanical analyses as influenced by rate and method of seeding. (July 21, 1947).

Experiment A

Rate Alfalfa-Grass	Method*	Average grams dry weight of individual species per plot								
		Alf.-Orchard grass			Alf.-Tall fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
	A	349	229	578	404	125	529	377	177	554
20-5	B	427	160	587	492	52	544	460	106	566
	M	415	178	593	450	93	543	432	135	567
Average		397	189	586	449	90	539	423	139	562
	A	382	251	633	372	147	519	377	199	576
20-10	B	403	188	591	486	86	572	445	137	582
	M	401	187	588	389	79	468	395	133	528
Average		395	209	604	416	104	520	406	156	562
	A	321	167	488	383	156	539	352	161	513
20-15	B	346	177	523	400	102	502	373	139	512
	M	332	200	532	385	89	474	359	145	504
Average		333	181	514	389	116	505	361	148	510
	A	344	252	596	370	133	503	357	193	550
10-10	B	286	183	469	427	70	497	357	126	483
	M	332	186	518	324	91	415	328	139	467
Average		321	207	528	374	98	472	347	153	500
	A	393	180	573	382	146	528	387	163	550
15-10	B	389	140	529	436	60	496	412	100	512
	M	374	183	557	423	82	505	399	133	532
Average		385	168	553	414	96	510	399	132	531
Grand average	A	358	216	574	382	141	524	370	179	549
	B	370	170	540	448	74	522	409	122	531
	M	371	187	558	394	87	481	383	137	519

L.S.D. Between:

		Alf.	Grass	Total
Mixtures	(.05)	N.S.	N.S.**	N.S.
	(.01)			
Rates	(.05)	N.S.	N.S.	N.S.
	(.01)			
Methods	(.05)	27	13	N.S.
	(.01)	36	18	
C.V.		13	18	9

*A = alternate rows, B = broadcast, and M = mixed in the row.

**Difference between the grasses closely approached significance at 5 per cent level.

TABLE 9. Seasonal botanical analyses of one seeding rate as influenced by method of seeding. (1947).

Experiment A

Rate Alfalfa-Grass	Method*	Average grams dry weight of individual species per plot								
		Alf.-Orchard grass			Alf.-Tall fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
May 8										
	A	390	167	557	365	182	547	377	174	551
20-10	B	433	137	570	420	176	595	426	157	583
	M	425	135	560	335	209	544	380	172	552
Average		416	146	562	373	189	562	394	168	562
July 21										
	A	382	252	633	372	147	519	377	199	576
20-10	B	403	188	591	486	86	572	445	137	582
	M	402	187	588	389	79	468	395	133	528
Average		395	209	604	416	104	520	406	156	562
August 25										
	A	476	115	591	457	128	585	466	122	588
20-10	B	502	100	602	536	75	611	519	88	607
	M	512	114	626	475	83	558	494	98	592
Average		497	111	606	490	95	585	493	103	596
October 8										
	A	295	43	338	257	168	426	276	106	382
20-10	B	402	29	431	372	86	457	387	57	444
	M	367	36	403	386	92	478	377	64	440
Average		355	36	391	339	115	454	347	76	422
Grand average	A	386	144	530	363	156	519	374	150	524
	B	435	114	548	454	106	559	444	110	554
	M	426	118	544	396	116	512	412	117	528
Average		416	125	541	404	126	530	410	126	535

*A = alternate rows, B = broadcast, and M = mixed in the row.

rates of seeding. This difference in total yield was largely due to the decrease in the yield of alfalfa.

At the dates of separations, similar yields of grass were obtained from plots receiving high seeding rates and those receiving low seeding rates. It was evident that the grass had influenced the establishment and growth of alfalfa prior to the harvest dates.

As shown in Table 9, tall fescue produced more forage in early spring and fall than did orchard grass. In summer months orchard grass was the highest yielding grass. When all plots were separated in July (Table 8), the yield of orchard grass was almost double that of tall fescue. With only one degree of freedom, such a difference is difficult to detect statistically.

The botanical analyses data for 1948 are presented in Tables 10, 11 and 13. Combined statistical analyses of the first and third harvest dates, in 1947 and 1948, are presented in Table 12. These analyses showed that in 1948 alfalfa continued to make more growth in the broadcast than in the mixed in the row or alternate row plots. It made the least growth in alternate rows. The grasses responded inversely. Mixed in the row seedings of alfalfa produced only slightly lower yields than broadcast seedings, particularly when grown with orchard grass.

TABLE 10. Botanical analyses as influenced by rate and method of seeding. (April 28, 1948).

Experiment A

Rate Alfalfa-Grass	Method*	Average grams dry weight of individual species per plot								
		Alf.-Orchard grass			Alf.-Tall Fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
20-5	A	426	212	638	348	290	638	387	251	638
	B	486	204	690	510	264	774	498	234	732
	M	467	227	694	401	281	682	434	254	688
Average		460	214	674	420	278	698	440	246	686
20-10	A	488	239	727	356	359	715	422	299	721
	B	496	194	690	476	242	718	486	218	704
	M	503	203	706	433	239	672	468	221	689
Average		496	212	708	422	280	702	459	246	705
20-15	A	353	184	537	341	270	611	347	227	574
	B	473	207	680	411	221	632	442	214	656
	M	434	196	630	358	236	594	396	216	612
Average		420	196	616	370	242	612	395	219	614
10-10	A	432	240	672	338	296	634	385	268	653
	B	392	193	585	428	265	693	410	229	639
	M	423	212	635	303	288	591	363	250	613
Average		416	215	631	356	283	639	386	249	635
15-10	A	443	152	595	329	258	587	386	205	591
	B	523	187	710	463	215	678	493	201	694
	M	466	185	651	484	273	757	475	229	704
Average		477	175	652	425	249	674	451	212	663
Grand average	A	428	205	633	342	295	637	385	250	635
	B	474	197	671	458	241	699	466	219	685
	M	459	205	664	396	263	659	427	234	661

L.S.D. Between:

		Alf.	Grass	Total
Mixtures	(.05)	N.S.	N.S.	N.S.
	(.01)			
Rates	(.05)	N.S.	N.S.	N.S.
	(.01)			
Methods	(.05)	31	20	N.S.
	(.01)	41		
C.V.		14	16	12

*A = alternate rows, B = broadcast, and M = mixed in the row.

TABLE 11. Botanical analyses as influenced by rate and method of seeding. (August 4, 1948).

Experiment A

Rate Alfalfa-Grass	Method*	Average grams dry weight of individual species per plot								
		Alf.-Orchard grass			Alf.-Tall fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
20-5	A	298	92	390	285	93	378	292	92	384
	B	378	48	426	373	45	418	376	47	423
	M	344	63	407	344	54	398	344	59	403
Average		340	68	408	334	64	398	337	66	403
20-10	A	353	58	411	310	82	392	332	70	402
	B	395	36	431	398	27	425	397	32	429
	M	392	45	437	391	28	419	392	37	429
Average		380	46	426	366	46	412	373	46	419
20-15	A	245	112	357	304	68	372	274	90	364
	B	316	64	380	345	40	385	331	52	383
	M	374	49	423	355	32	387	364	41	405
Average		312	75	387	334	47	381	323	61	384
10-10	A	341	75	416	317	81	398	329	78	407
	B	321	53	374	362	28	390	342	41	383
	M	327	77	404	288	40	328	308	59	369
Average		330	68	398	322	50	372	326	59	385
15-10	A	314	63	377	312	72	384	313	68	381
	B	349	40	389	375	32	407	362	36	398
	M	352	60	412	366	39	405	359	50	409
Average		338	54	392	351	48	399	345	51	396
Grand average	A	310	80	390	306	79	385	308	80	388
	B	352	48	400	371	34	405	361	41	402
	M	358	59	417	349	39	388	353	49	402

L.S.D. Between:		Alf.	Grass	Total
Mixtures	(.05)	N.S.	N.S.	N.S.
	(.01)			
Rates	(.05)	N.S.	N.S.	N.S.
	(.01)			
Methods	(.05)	23	10	N.S.
	(.01)	31	13	
C.V.		13	34	10

*A = alternate rows, B = broadcast, and M = mixed in the row.

TABLE 12. Combined analyses of variance of botanical separation of first and third harvests in grams per plot (1947 and 1948)

Experiment A

Source of variation	Degrees of freedom	Total	Mean Square Alfalfa	Grass
		May 8 and July 21, 1947		
Whole plots	5			
Replications	2	38,825	62,362	3,797
Mixtures	1	25,671 N.S.	1,895 N.S.	41,516 N.S.
Error (a)	2	41,896	43,210	28,750
Split plots	24			
Rates	4	81,370*	67,542N.S.	17,017 N.S.
Rate x mixt.	4	14,834 N.S.	3,912N.S.	11,620 N.S.
Error (b)	16	22,164	24,951	8,249
Split-split plots	60			
Methods	2	2,917 N.S.	56,112**	39,461**
Meth. x rates	8	16,340 N.S.	7,925N.S.	2,235 N.S.
Meth. x mixt.	2	19,478 N.S.	14,314N.S.	11,518 N.S.
Meth. x rate x mixt.	8	15,360 N.S.	10,136N.S.	5,232 N.S.
Error (c)	40	12,707	10,788	5,150
Total	89			
		April 28 and August 4, 1948		
Whole plots	5			
Replications	2	76,236	57,170	10,939
Mixtures	1	11 N.S.	64,160N.S.	62,515 N.S.
Error (a)	2	6,757	60,068	33,731
Split plots	24			
Rates	4	46,525 N.S.	47,577N.S.	7,558 N.S.
Rate x mixt.	4	2,060 N.S.	2,514N.S.	1,864 N.S.
Error (b)	16	23,629	33,903	3,974
Split-split plots	60			
Methods	2	32,120*	138,510**	37,303**
Meth. x rates	8	13,834 N.S.	10,514N.S.	3,391 N.S.
Meth. x mixt.	2	8,291 N.S.	17,968N.S.	7,277 N.S.
Meth. x rate x mixt.	8	9,610 N.S.	8,918N.S.	1,098 N.S.
Error (c)	40	7,889	7,833	2,406
Total	89			

TABLE 13. Seasonal botanical analyses of one seeding rate as influenced by method of seeding. (1948).

Experiment A

Rate Alfalfa-Grass	Method*	Average grams dry weight of individual species per plot								
		Alf.-Orchard grass			Alf.-Tall fescue			Average		
		Alf.	Orch.	Total	Alf.	Fes.	Total	Alf.	Grass	Total
April 28										
	A	488	240	728	356	358	714	422	299	721
20-10	B	496	194	690	475	243	718	486	218	704
	M	503	204	707	433	239	672	468	222	690
Average		496	213	709	421	280	701	459	246	705
June 8										
	A	417	57	474	374	64	438	396	60	456
20-10	B	421	82	503	463	36	498	442	59	501
	M	402	88	490	434	39	473	418	64	482
Average		413	76	489	424	46	470	418	61	479
August 4										
	A	353	58	411	310	82	392	332	70	402
20-10	B	395	36	431	398	27	425	396	32	428
	M	392	45	437	391	28	419	392	36	428
Average		380	46	426	366	46	412	373	46	419
September 9										
	A	330	20	350	285	38	324	308	29	337
20-10	B	330	30	360	356	21	377	343	25	368
	M	358	25	383	329	34	363	344	30	373
Average		339	25	364	323	31	355	331	28	359
Grand average	A	397	94	491	331	136	467	364	114	479
	B	410	86	496	423	82	504	417	84	500
	M	414	90	504	397	85	482	406	88	493
Average		407	90	497	384	101	484	396	95	491

*A = alternate rows, B = broadcast, and M = mixed in the row.

Although not significant, there was somewhat less alfalfa produced, in 1948, in plots receiving a high seeding rate of grass. There were no differences between seeding rates in the amount of grass present. As noted in Table 13, orchard and fescue exhibited similar seasonal growth in 1948 as in the previous year.

Alfalfa produced lower yields in alternate rows than in mixed in the row, or broadcast. This reduction in yield may be attributed partially to lack of optimum spacing of the alfalfa plants and partially to increased growth of grass in alternate rows.

In the grand average summaries of Tables 9 and 13, the treatment variables are presented for all dates of harvest of one seeding rate. In both years similar yields of alfalfa were obtained from broadcast plots when grown with orchard or tall fescue. There was somewhat less alfalfa produced, however, in the alternate row and mixed in the row plots when grown with tall fescue than when grown with orchard grass.

Chemical analyses

Nitrogen analyses were made on orchard grass and tall fescue on the botanically separated samples of seeding rate treatments 20-5, 20-20 and 10-10, under all managements (Tables 14 and 15). There were small differences in the nitrogen contents of tall fescue and orchard grass. Rate of

TABLE 14. Seasonal nitrogen content of the grass component of the mixture as influenced by the rate and method of seeding. (1947).

Experiment A

Rate Alfalfa-Grass	Meth-od*	Average per cent nitrogen content of the grass component									
		Alfalfa-Orchard grass					Alfalfa-Tall fescue				
		Orchard					Fescue				
		May 8	July 21	Aug. 25	Oct. 8	Ave.	May 8	July 21	Aug. 25	Oct. 8	Ave.
	A	1.88	2.73			2.31	2.03	2.98			2.51
20-5	B	1.91	3.05			2.48	2.31	3.30			2.81
	M	1.97	3.01			2.49	2.18	3.13			2.66
Average		1.92	2.93			2.43	2.17	3.14			2.66
	A	1.87	2.70	3.01	3.17	2.69	1.90	2.75	2.96	3.10	2.68
20-10	B	2.21	2.93	3.06	3.34	2.88	2.14	3.08	3.12	3.16	2.88
	M	2.08	3.00	3.20	3.33	2.90	2.16	2.95	2.94	3.11	2.79
Average		2.05	2.88	3.09	3.28	2.82	2.07	2.93	3.01	3.12	2.78
	A	1.96	2.61			2.29	1.83	2.77			2.30
10-10	B	2.05	2.76			2.41	1.92	3.03			2.48
	M	2.01	2.76			2.39	1.89	2.80			2.35
Average		2.01	2.71			2.36	1.88	2.87			2.38
Grand average	A	1.90	2.68			2.29	1.92	2.83			2.38
	B	2.06	2.91			2.49	2.12	3.14			2.63
	M	2.02	2.92			2.47	2.08	2.96			2.52

L.S.D Between:		May 8	July 21
Mixtures	(.05)	N.S.	N.S.
	(.01)		
Rates	(.05)	N.S.	.11
	(.01)		.16
Methods	(.05)	.11	.07
	(.01)	.14	.09
C.V.		8	4

*A = alternate rows, B = broadcast, and M = mixed in the row.

TABLE 15. Seasonal nitrogen content of the grass component of the mixture as influenced by rate and method of seeding. (1948).

Experiment A

Rate Alfalfa-Grass	Method*	Average per cent nitrogen content of the grass component									
		Alfalfa-Orchard grass					Alfalfa-Tall fescue				
		Orchard					Fescue				
		Apr. 28	June 8	Aug. 4	Sept. 9	Ave.	Apr. 28	June 8	Aug. 4	Sept. 9	Ave.
20-5	A	1.95		2.83		2.39	2.03		2.81		2.42
	B	2.13		3.61		2.87	2.06		3.14		2.60
	M	2.13		3.36		2.75	2.08		3.30		2.69
Average		2.07		3.27		2.67	2.06		3.08		2.57
20-10	A	2.15	3.33	3.00	3.04	2.88	1.90	3.04	2.73	2.84	2.63
	B	2.09	3.32	3.71	3.12	3.06	2.03	3.26	3.45	3.25	3.00
	M	2.17	3.24	3.63	3.15	3.05	2.02	3.16	3.64	3.04	2.96
Average		2.14	3.30	3.45	3.10	3.00	1.98	3.15	3.27	3.04	2.86
10-10	A	2.10		3.06		2.58	1.84		2.64		2.24
	B	2.20		3.52		2.86	1.99		3.33		2.66
	M	2.03		3.45		2.74	1.83		3.31		2.57
Average		2.11		3.34		2.73	1.89		3.09		2.49
Grand average	A	2.07		2.96		2.52	1.92		2.73		2.33
	B	2.14		3.61		2.88	2.03		3.31		2.67
	M	2.11		3.48		2.80	1.98		3.42		2.70

L.S.D. Between:		April 28	August 4
Mixtures	(.05)	N.S.	.19
	(.01)		
Rates	(.05)	N.S.	N.S.
	(.01)		
Methods	(.05)	.07	.21
	(.01)		.28
C.V.		5	9

*A = alternate rows, B = broadcast, and M = mixed in the row.

seeding did not affect substantially the nitrogen content of these grasses. Both grasses analyzed slightly higher in per cent nitrogen in the broadcast and mixed in the row plots than in the alternate row plots.

Experiment B

Yields

The individual alternate rows of alfalfa and grass were harvested separately, and the seasonal and total yields for 1947 and 1948 are reported in Table 16. The wide row plots received twice as many seed per row as the narrow row plots, but the rate per acre was the same.

In 1947, the mixture containing tall fescue was saved. In 1948, the alfalfa-orchard grass mixture produced more total forage than the alfalfa-fescue mixture in narrowly spaced rows. In Experiment A, the differences in yield of total forage between these mixtures were not significant. In the widely spaced rows alfalfa-fescue produced more forage than the mixture of alfalfa and orchard grass. Tall fescue in particular was favored by wide spacing of rows; whereas orchard grass produced less forage per acre when planted in widely spaced rows.

As in Experiment A, alfalfa produced lower yields in alternate rows, spaced six inches, with tall fescue than

TABLE 16. Seasonal yields in pounds dry matter per acre as influenced by width of spacing in alternate rows. (1947 and 1948).

Experiment B

Treatments*		1947					
Spacing -	Species	May 8	June 16	July 21	Aug. 25	Oct. 9	Total
6"	Alfalfa	968	486	1141	1019	562	4176
	Fescue	399	126	409	338	464	1736
	Total						5912
12"	Alfalfa	628	417	991	899	551	3486
	Fescue	454	148	334	322	294	1552
	Total						5038

		1948				
		April 28	June 8	Aug. 4	Sept. 9	Total
6"	Alfalfa	979	904	912	628	3423
	Fescue	796	288	183	106	1373
	Total					4796
12"	Alfalfa	920	898	922	511	3251
	Fescue	1024	353	229	136	1742
	Total					4993
6"	Alfalfa	1134	1049	1122	1004	4309
	Orchard	796	413	272	127	1608
	Total					5917
12"	Alfalfa	956	861	966	670	3453
	Orchard	370	258	212	87	927
	Total					4380

* Alfalfa-orchard grass plots were harvested and discarded in the field in 1947 because of heavy infestation of weeds.

All plots were seeded at the rate of 20 pounds alfalfa and 10 pounds grass per acre.

with orchard grass. As shown in Table 16, tall fescue produced less forage than orchard grass in six inch spacings with alfalfa; yet, the growth of alfalfa was suppressed in the alfalfa-fescue mixture to the greatest extent. In rows spaced twelve inches, alfalfa produced approximately the same amount of forage with both grasses. The competition between species was minimized in the widely spaced rows. The wider spacing produced more alfalfa per row than narrow spacing. However, the additional yield per row was not sufficient to equal two rows of alfalfa in a narrow row plot.

The growth obtained from the individual species, in widely spaced rows, was not sufficient to justify the wider spacing in alternate rows. The alfalfa-orchard grass mixture planted in six-inch alternate rows yielded more total forage than the other spacings. The weeds were more numerous under wider spacing.

Chemical analyses

Both grasses analyzed higher in per cent nitrogen planted in narrow rows with alfalfa than when planted in wide rows with alfalfa (Table 17). There were small differences in per cent nitrogen between the grasses. Alfalfa analyzed similarly in per cent nitrogen in both spacings.

TABLE 17. Seasonal nitrogen content of the individual species as influenced by width of spacing in alternate rows. (1947 and 1948).

Experiment B

Average per cent nitrogen content of the individual species

Treatments*		1947				
Spacing -	Species	May 8	June 16	July 21	Aug. 25	Average
6"	Alfalfa	2.85	3.38	3.41	3.23	3.22
	Fescue	1.71	2.23	2.66	2.77	2.34
12"	Alfalfa	2.95	3.26	3.35	3.20	3.19
	Fescue	1.52	2.08	2.42	2.49	2.13

		1948				
		April 28	June 8	Aug. 4	Sept. 9	Average
6"	Alfalfa	2.80	3.74	3.33	3.29	3.29
	Fescue	1.94	2.69	3.10	2.83	2.64
12"	Alfalfa	2.87	3.64	3.28	3.26	3.26
	Fescue	1.54	2.40	2.91	2.61	2.36
6"	Alfalfa	2.83	3.58	3.32	3.23	3.24
	Orchard	1.92	3.08	3.15	2.96	2.78
12"	Alfalfa	2.69	3.75	3.25	3.21	3.22
	Orchard	1.71	2.73	2.95	2.75	2.54

* Alfalfa-orchard grass plots were harvested and discarded in 1947 because of heavy infestation of weeds.

Experiment C

Yields

In Table 18, the seasonal yields for 1948 are presented for alfalfa and orchard grass. These species were grown in adjacent rows, with and without partitioned root systems by sheet metal barriers. The analyses of variances are reported in Table 19.

Orchard grass produced more growth when grown between two rows of alfalfa than between two rows of orchard grass, both with and without partitioned root systems. There was no difference in the growth of orchard grass between partitioned and nonpartitioned blocks, in the first year.

The average yield of four harvests of rows of orchard grass grown adjacently to rows of orchard grass (O-O-O), with root systems of the rows partitioned, was 25 grams of forage. An average yield of 37 grams of forage was obtained from orchard grass rows grown adjacently to alfalfa rows (A-O-A), with root systems partitioned. The row of orchard grass bordered on one side by orchard grass and the other by alfalfa (O-O-A) produced 32 grams of forage. This increased growth arose from an above ground cause. It may be a direct above ground effect in that the air temperature was reduced to an optimum level by the larger canopy of growth produced by alfalfa. It may be partially an indirect above ground effect on soil moisture evaporation.

TABLE 18. Seasonal yields of alfalfa and orchard grass grown in six-inch spaced rows in pure stands and alternately as influenced by species combination and partitioning and nonpartitioning of root systems. (1948).

Experiment C

Row order of species	Average grams dry weight of individual species per row									
	May 3		June 10		Aug. 18		Oct. 1		Average	
	P.	No P.	P.	No P.	P.	No P.	P.	No P.	P.	No P.
O	57	61	10	12	21	25	8	11	24	27
O*	57	74	11	14	21	25	10	13	25	32
O	64	69	14	16	20	26	8	11	27	31
O*	73	52	19	17	23	24	11	9	32	26
A	51	58	40	50	61	94	56	89	52	73
O	78	70	23	26	29	33	10	9	35	35
A**	50	64	40	46	64	86	53	70	52	67
O*	82	79	28	34	28	27	10	6	37	37
A	53	59	41	45	59	82	54	68	52	64
O	90	88	33	49	31	35	11	10	41	46
A**	44	59	38	41	53	68	45	54	45	56
A	50	45	39	36	53	58	41	38	46	44
A**	48	54	39	39	54	56	41	39	46	47
A	52	59	42	42	60	53	42	41	49	49

L.S.D.		May 3	June 10	Aug. 18	Oct. 1	Average
Orchard (O) Between:						
Rows	(.05)	12	4	N.S.	2	5
	(.01)	N.S.	6		N.S.	7
P. and No P.	(.05)	N.S.	N.S.	N.S.	N.S.	N.S.
P. x Row	(.05)	N.S.	N.S.	N.S.	N.S.	N.S.
Alfalfa (A) Between:						
Rows	(.05)	N.S.	N.S.	8	4	5
	(.01)			12	6	7
P. and No P.	(.05)	6	N.S.	3	7	4
	(.01)	11		4	12	5
P. x Row	(.05)	N.S.	N.S.	N.S.	6	7
	(.01)				9	N.S.

* Analyses of variance were computed on these three orchard grass rows.
** Analyses of variance were computed on these three alfalfa rows.

TABLE 19. Combined analyses of variance for the four harvests in grams per row of dry matter (1948)

Experiment C

Source of variation	Analyses of variance* Degrees of freedom		Mean square
Alfalfa rows			
Whole plots		14	
Replications	4		2,850
Treatments	2		7,089**
Error (a)	8		361
Split plots		15	
Partitions	1		9,612**
Part. x treat.	2		1,872*
Error (b)	12		373
Total		29	
Orchard grass rows			
Whole plots		14	
Replications	4		5,542
Treatments	2		3,745**
Error (a)	8		304
Split plots		15	
Partitions	1		1 N. S.
Part. x treat.	2		1,492 N. S.
Error (b)	12		1,202
Total		29	

* The least significant differences and coefficients of variation are noted with data in tables.

Little of the increased growth obtained from orchard grass grown adjacently to alfalfa, without root partitions, could be attributed to nitrogen excretion, or sloughing of nodules or roots in the first year. The magnitude of increase was similar in the partitioned plots and the nonpartitioned plots. The results of the first harvest of the second year will be discussed subsequently.

In the nonpartitioned block (Table 18) individual rows of alfalfa, in 1948, yielded an average of 67 grams per cutting when grown adjacently to two orchard grass rows (O-A-O), and 47 grams when grown adjacently to two alfalfa rows (A-A-A). An average yield of 56 grams per cutting was obtained from alfalfa rows bordered by alfalfa on one side and orchard grass on the other (A-A-O). In the partitioned block individual rows of alfalfa yielded an average of 52 grams per cutting when grown adjacently to two orchard grass rows (O-A-O), and 46 grams when grown adjacently to two alfalfa rows (A-A-A). Part of this reduction in growth arose from above ground competition, but the below ground effect was of greater magnitude.

Lower yields of individual rows of alfalfa were obtained from the partitioned than from the nonpartitioned blocks, except where bordered by two alfalfa rows in the nonpartitioned block. The sheet metal partitions confined the alfalfa roots to a zone 6 inches in width. Consequently, maximum lateral spread of the root systems was prevented. The growth of alfalfa bordered by alfalfa (A-A-A) was similar in the partitioned and nonpartitioned blocks.

In the nonpartitioned blocks, the row of orchard grass in pure stand (O-O-O), and the row of alfalfa in pure stand (A-A-A) produced a total average yield of 79 grams of forage. The total average yield of a row of orchard grass in alternate row (A-O-A), and a row of alfalfa in alternate row (O-A-O) was 104 grams. As evidenced, mixtures of alfalfa and orchard grass planted on a unit area produced more forage than the same unit area planted in pure stands of each species. A pure stand of the highest yielding species may produce more growth than a mixture. However, in this investigation, lower yields of alfalfa were obtained in pure stands than in alternate rows with orchard grass.

During the summer and fall months considerably more forage was produced by alfalfa than by orchard grass. An unidentified fungus disease weakened the stand of orchard grass prior to the last harvest.

In previous observations, grasses interplanted with alfalfa have shown marked increases in growth in the spring of the second year. The results of the first harvest of the second year are presented in Table 20. As shown, orchard grass produced more growth when grown between two rows of alfalfa (A-O-A) than between two rows of orchard grass (O-O-O). The magnitude of

TABLE 20. Yields of alfalfa and orchard grass grown in six-inch spaced rows in pure stands and alternately as influenced by species combination and partitioning and nonpartitioning of root systems (April 29, 1949)

Experiment C

Row order of species	Average grams dry weight of individual species per row	
	Partitioned	Nonpartitioned
O	5	7
O*	6	10
O	8	16
O*	15	27
A	58	89
O	28	42
A**	62	73
O*	29	38
A	57	67
O	29	55
A**	51	54
A	49	47
A**	46	45
A	51	50

* Principal rows of orchard grass studied.

** Principal rows of alfalfa studied.

the increase was considerably larger in the nonpartitioned plots than in the partitioned plots (Table 20). In 1948, the magnitude of the increase was similar in partitioned and nonpartitioned plots. The average yield of rows of orchard grass grown adjacently to rows or orchard grass, nonpartitioned, was 10 grams of forage. An average yield of 38 grams of forage was obtained from orchard grass rows grown adjacently to alfalfa rows, nonpartitioned.

In the first year following seeding, orchard grass was benefitted largely by its above ground association with alfalfa. In the spring of the second year, orchard grass was benefitted by both its above and below ground association with alfalfa. Similar growth responses of alfalfa, in the various combinations, were obtained in both years.

Chemical analyses

Nitrogen analyses, Table 21, showed that there was more nitrogen present in orchard grass grown adjacently to alfalfa than when grown in pure stands. The beneficial effect was of greater magnitude in nonpartitioned blocks.

Alfalfa analyzed similarly in per cent nitrogen in pure stands and alternate rows.

Soil moisture

Alfalfa and orchard grass were planted in rows spaced six inches, in pure stands and in alternate rows, with and without

TABLE 21. Seasonal nitrogen content of alfalfa and orchard grass in six-inch spaced rows in pure stands and alternately as influenced by species combination and partitioning and nonpartitioning of the root systems. (1948)

Experiment C

Row order of species	Average per cent nitrogen content of the individual species									
	May 3		June 10		Aug. 18		Oct. 1		Average	
	P.	No P.	P.	No P.	P.	No P.	P.	No P.	P.	No P.
O										
O*	1.43	1.54	1.88	2.23	2.12	2.15	2.48	2.34	1.97	2.07
O										
O*	1.50	1.64	2.10	2.29	2.32	2.35	2.63	2.81	2.14	2.27
A										
O										
A**	2.70	2.65	3.43	3.35	3.15	3.05	3.09	3.12	3.09	3.04
O*	1.63	1.81	2.39	2.49	2.60	2.62	2.92	2.98	2.39	2.48
A										
O										
A										
A										
A**	2.71	2.78	3.49	3.52	3.07	3.03	3.21	3.10	3.12	3.11
A										

* Row of orchard grass spaced six inches from adjacent rows

** Row of alfalfa spaced six inches from adjacent rows.

partitioned root systems. Moisture blocks were placed at various depths directly under the center row of the three-row combinations listed below:

O - O - O

A - A - A

A - O - A

O - A - O

Moisture determinations obtained in 1948, in percentage of moisture and ohms resistance, are given in Tables 2, 3, 4, and 5 of the Appendix. A total of 55 readings were made from April 21 to September 20. No readings were made June 21 through July 16 because of the extreme drought condition. On June 20, most of the moisture blocks read well over 100,000 ohms resistance, which is considered dry. Although no complete readings were made June 21 through July 16, it was evident that the soil was dryer than 100,000 ohms at all levels throughout most of this period.

<u>Laboratory calibrations.</u> The ranges in per cent moisture that were measurable with the Bouyoucos blocks are shown in Table 22, as determined in the laboratory. The resistances in ohms obtained for the various percents of measurable moisture are presented in Figure 1 (Appendix).

Field capacity determinations were not made in this study. It was evident from Figure 1 (Appendix) and Table 22 that the Bouyoucos block method was well adapted to measure changes in

TABLE 22. Laboratory determinations of per cent soil moisture present in the various soil layers from the permanent wilting percentage to saturation and per cent soil moisture present at upper range of sensitivity of Bouyoucos bridge. (Cecil sandy clay loam).

Experiment C

Soil Layers	Per cent soil moisture: Permanent wilting	Per cent soil moisture: Upper range of sensitivity*	Per cent soil moisture: Saturation
0-6"	5.4	12.0	30.3
6-12"	8.2	17.0	30.4
12-18"	14.9	22.0	36.0
18-24"	18.2	27.0	44.4
24-30"	20.1	30.0	50.6

* The Bouyoucos bridge was not sensitive to moisture in excess of this amount.

soil moisture from the wilting percentage to near field capacity. Changes in soil moisture from saturation to slightly below the estimated field capacity were not measurable by this method.

As shown in Figure 1 (Appendix), the biologically calculated permanent wilting percentages were correlated with a reading of 500,000 to 800,000 ohms resistance at all soil depths. Some investigators (9)(48) have considered a resistance of 75,000 ohms as the wilting percentage; Bouyoucos (9) theorized that 1,000,000 ohms may be a better index of the wilting percentage. The higher readings probably are obtained by severely wilting the plants before determining per cent moisture and ohms resistance. The method is quite arbitrary as to the determination of the exact wilting percentage.

Readings of 800,000 ohms or higher were rarely attained in the field, even during severe droughts. It was evident from this study that rather severe wilting could occur at readings of approximately 100,000 ohms.

In all soil layers only 2.5 to 3.0 per cent available moisture remained at 75,000 ohms resistance. It is not known at what range in ohms resistance water becomes a limiting factor in plant growth; however, it is generally agreed that water is not equally available at all per cents between field capacity and wilting percentage.

Pure stand relationships (ohms resistance). In Tables 23 and 24 are presented the number of days resistance readings of more than 10,000 and more than 75,000 ohms were obtained under pure stands of orchard grass and alfalfa. The data are summarized in two periods, April 21-June 20, and July 17-September 20. Most of the blocks read well over 100,000 ohms, on June 20, and no further readings were made until after rain began on July 13. Excavations of alfalfa and orchard grass plants growing adjacently to this experiment were made in October, 1948. These plants were seeded the same date as Experiment C. The roots of alfalfa and orchard grass had permeated the soil to a maximum depth of 36 inches. The alfalfa roots were well distributed downward to 36 inches; whereas, a large proportion of the orchard grass roots were located in the upper 12 inches (Figure 5). It was evident that the soil was dryer throughout the season under alfalfa than under orchard grass at all depths. During the spring months, orchard grass produced approximately as much growth as alfalfa. The soil was almost as deficient in moisture under orchard grass as under alfalfa at the 3, 6 and 12-inch levels. At the lower levels, 24 and 30 inches, alfalfa removed the moisture down to tensions of over 75,000 ohms on several more days than did orchard grass.

During midsummer and fall over twice as much forage was produced by alfalfa as by orchard grass, and the differences

TABLE 23. Number of days in 1948 on which indicated resistance readings were obtained at various depths under pure stands of alfalfa and orchard grass (No partitions).

Experiment C

Seeding	Depth in inches	More than 10,000 ohms — Periods during which blocks were read approx. 3 times wkly. April 21–June 20		July 17–Sept. 20		Totals	
0-0-0	3	18	(22)*	3	(33)*	21	(55)*
	6	19	(22)	6	(33)	25	(55)
	12	20	(22)	12	(33)	32	(55)
	24	16	(22)	16	(33)	32	(55)
	30	15	(22)	11	(33)	26	(55)
A-A-A	3	21	(22)	16	(33)	37	(55)
	6	21	(22)	18	(33)	39	(55)
	12	21	(22)	24	(33)	45	(55)
	24	20	(22)	27	(33)	47	(55)
	30	20	(22)	27	(33)	47	(55)
		More than 75,000 ohms					
0-0-0	3	13	(22)	0	(33)	13	(55)
	6	15	(22)	0	(33)	15	(55)
	12	17	(22)	7	(33)	24	(55)
	24	10	(22)	9	(33)	19	(55)
	30	2	(22)	7	(33)	9	(55)
A-A-A	3	15	(22)	4	(33)	19	(55)
	6	17	(22)	7	(33)	24	(55)
	12	20	(22)	18	(33)	38	(55)
	24	18	(22)	15	(33)	33	(55)
	30	9	(22)	8	(33)	17	(55)

* Number of days on which readings were made during indicated periods.

TABLE 24. Number of days in 1948 on which indicated resistance readings were obtained at various combinations of depths under pure stands of orchard grass and alfalfa (No partitions).

Experiment C

Seeding	Periods during which blocks were read approx. 3 times wkly.					
	April 21–June 20		July 17–Sept. 20		Totals	
			Depths of 3, 6 and 12 inches More than 10,000 ohms			
0-0-0	17	(22)*	0	(33)*	17	(55)*
A-A-A	21	(22)	13	(33)	34	(55)
			More than 75,000 ohms			
0-0-0	11	(22)	0	(33)	11	(55)
A-A-A	14	(22)	4	(33)	18	(55)
			Depths of 3, 6, 12, 24 and 30 inches			
			More than 10,000 ohms			
0-0-0	12	(22)	0	(33)	12	(55)
A-A-A	20	(22)	12	(33)	32	(55)
			More than 75,000 ohms			
0-0-0	2	(22)	0	(33)	2	(55)
A-A-A	8	(22)	4	(33)	12	(55)

* Number of days on which readings were made during indicated periods.

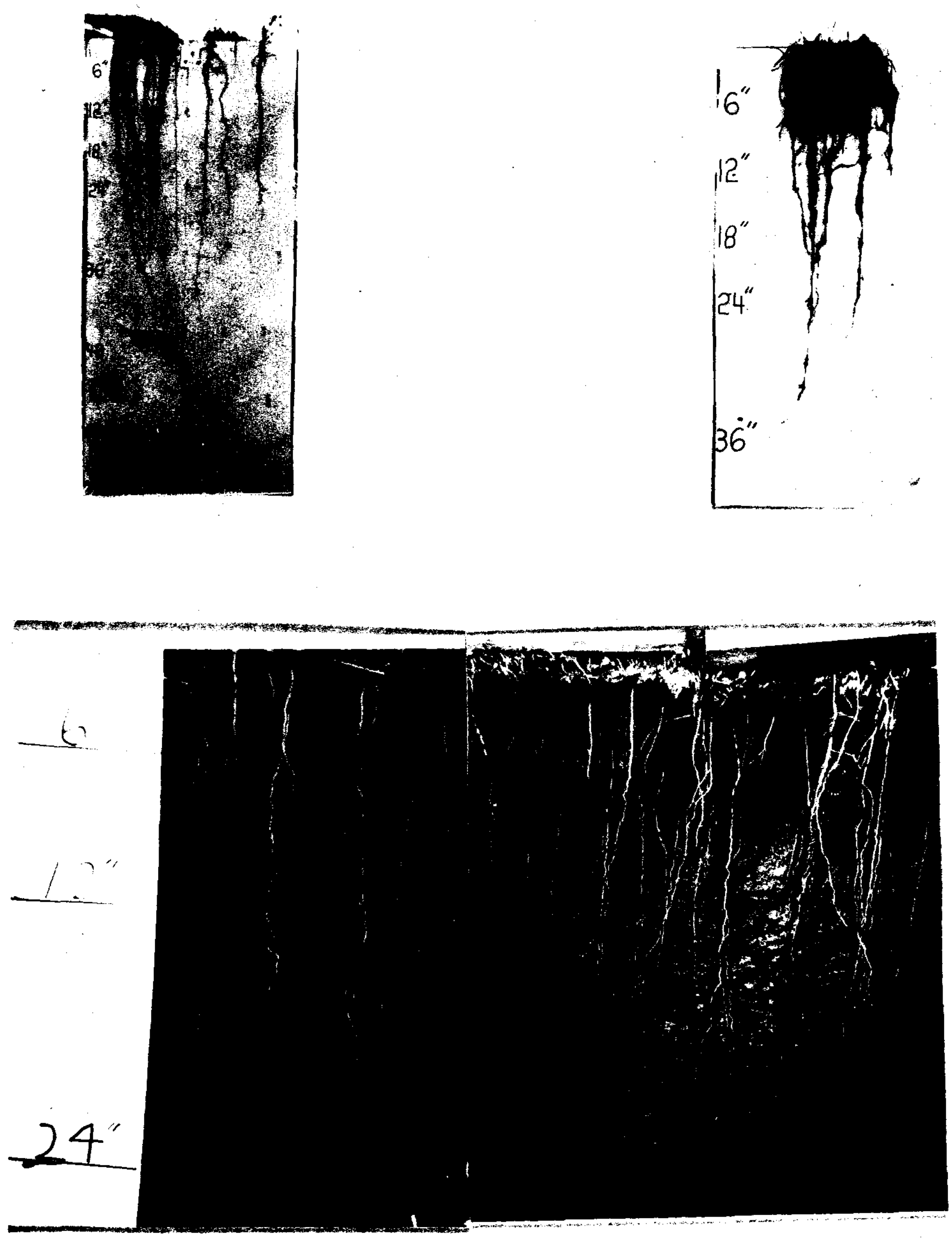


Figure 5. Top: Left. One year old alfalfa roots
Right. One year old orchard grass roots.

Bottom: One year old alfalfa roots in <u>situ</u>.

Experiment C (Cecil sandy clay loam)

in usage of moisture between the two plants were much larger than during the spring. From July 17 to September 20, alfalfa removed the moisture down to tension of over 10,000 and 75,000 ohms at practically all depths on more than twice as many days as did orchard grass. At the 30-inch depth orchard grass and alfalfa reached a dryness of 75,000 ohms on a similar number of days; however, all of this dryness was a carry-over from the june drought. The soil was not moistened at the 30-inch level until early August.

It is shown in Table 23 that a dryness of over 75,000 ohms was obtained more frequently at the 12 inch depth than at any other depth under both orchard grass and alfalfa. The upper level of soil was replenished with light showers and the lower level contained fewer roots.

The data in Table 23 refer to resistance readings at specific depths. In Table 24, the data are summarized according to combinations of depths. On 22 per cent of the days, the soil was dryer than 75,000 ohms at all depths under alfalfa. All blocks were dryer than 100,000 ohms from June 20 to approximately July 16. The period from April 20-June 20 was much more deficient in rainfall than the period July 17-September 20.

In Figures 6, 7 and 8, moisture tensions at 3, 12 and 30 inches are graphically plotted for alfalfa and orchard grass. It is further evidenced from these graphs that alfalfa used

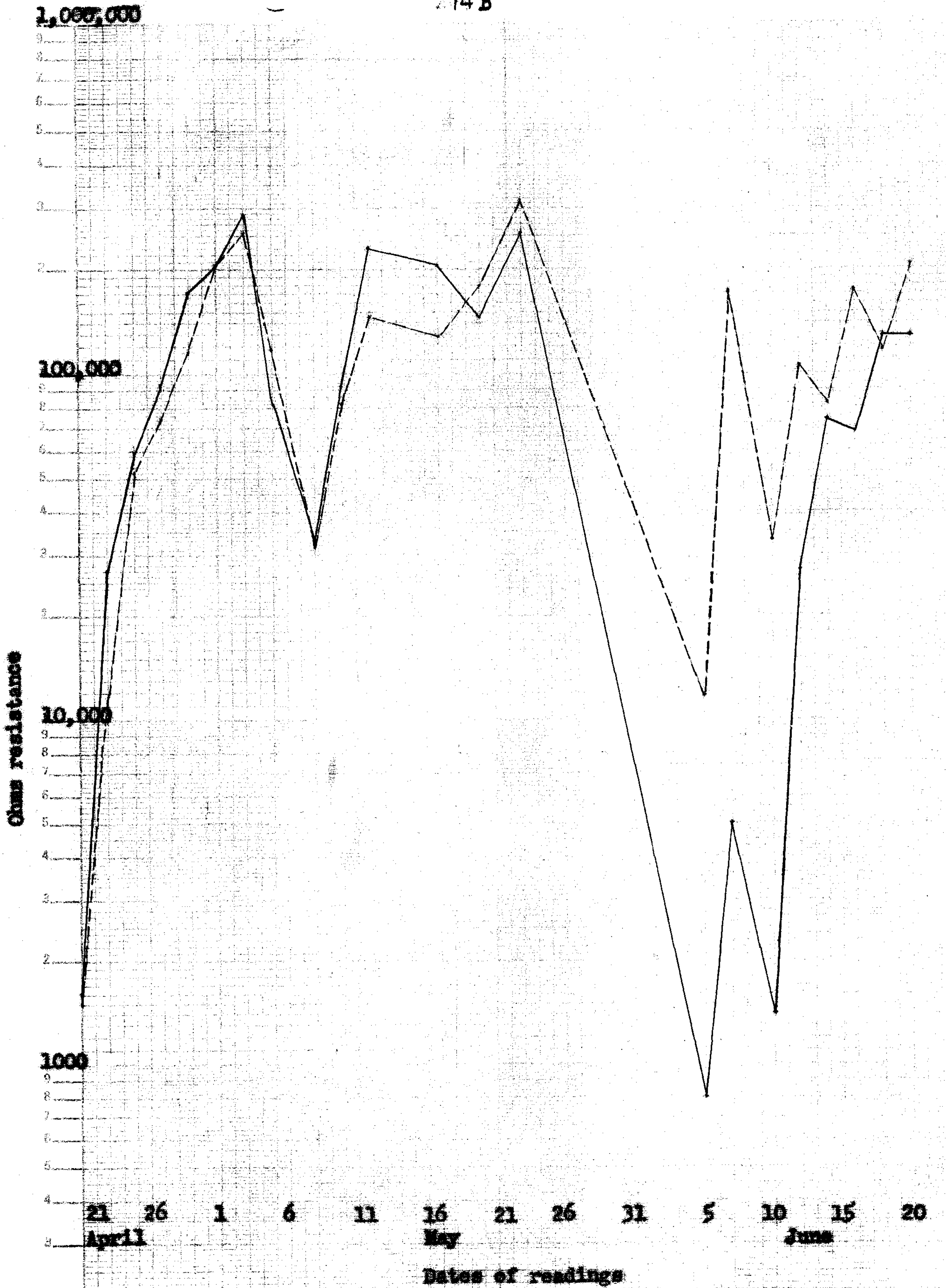


Figure 6. Seasonal moisture tensions as influenced by seeding combinations of alfalfa and orchard grass planted in rows spaced six inches. (No partitions)

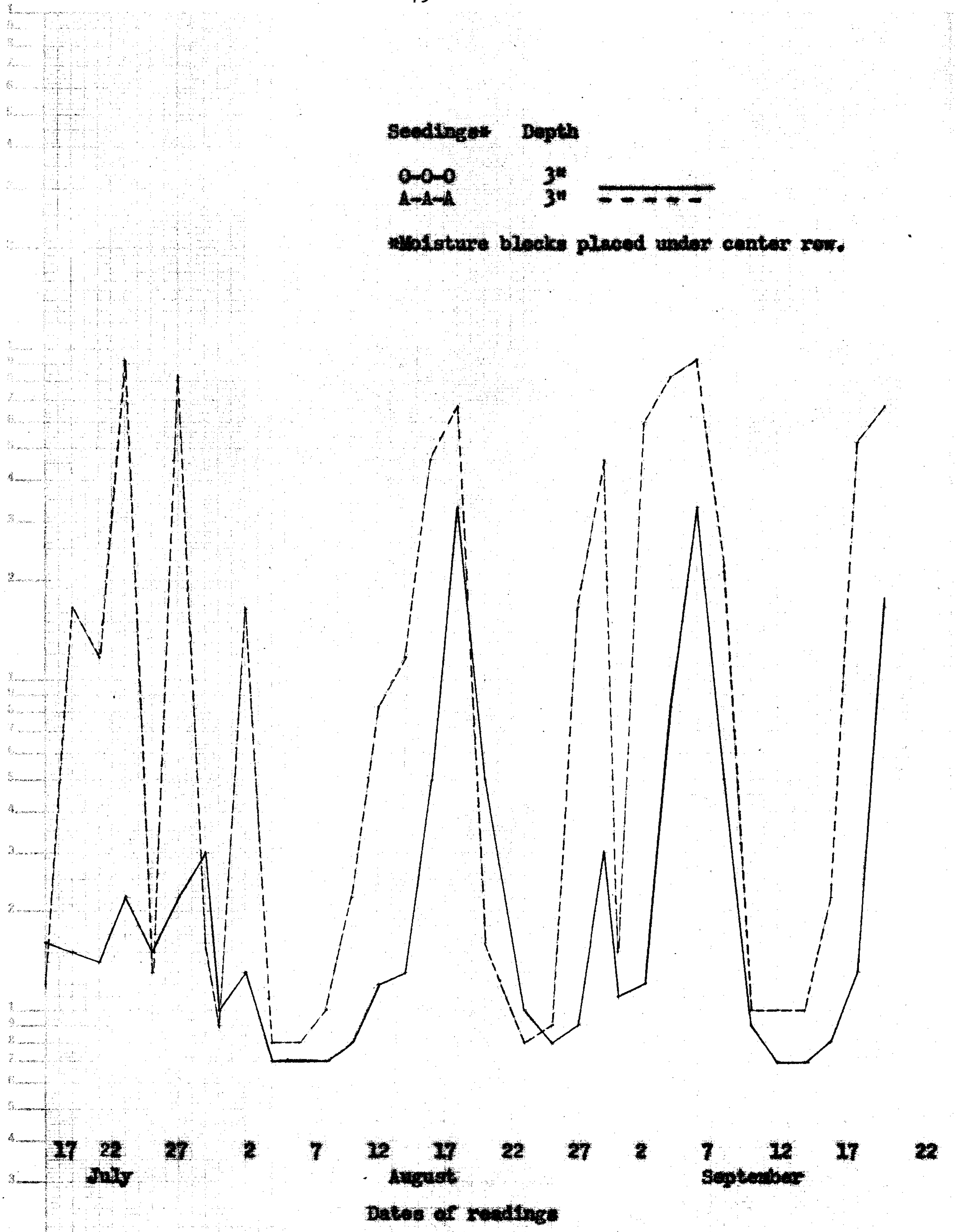


Figure 6 (Continued)

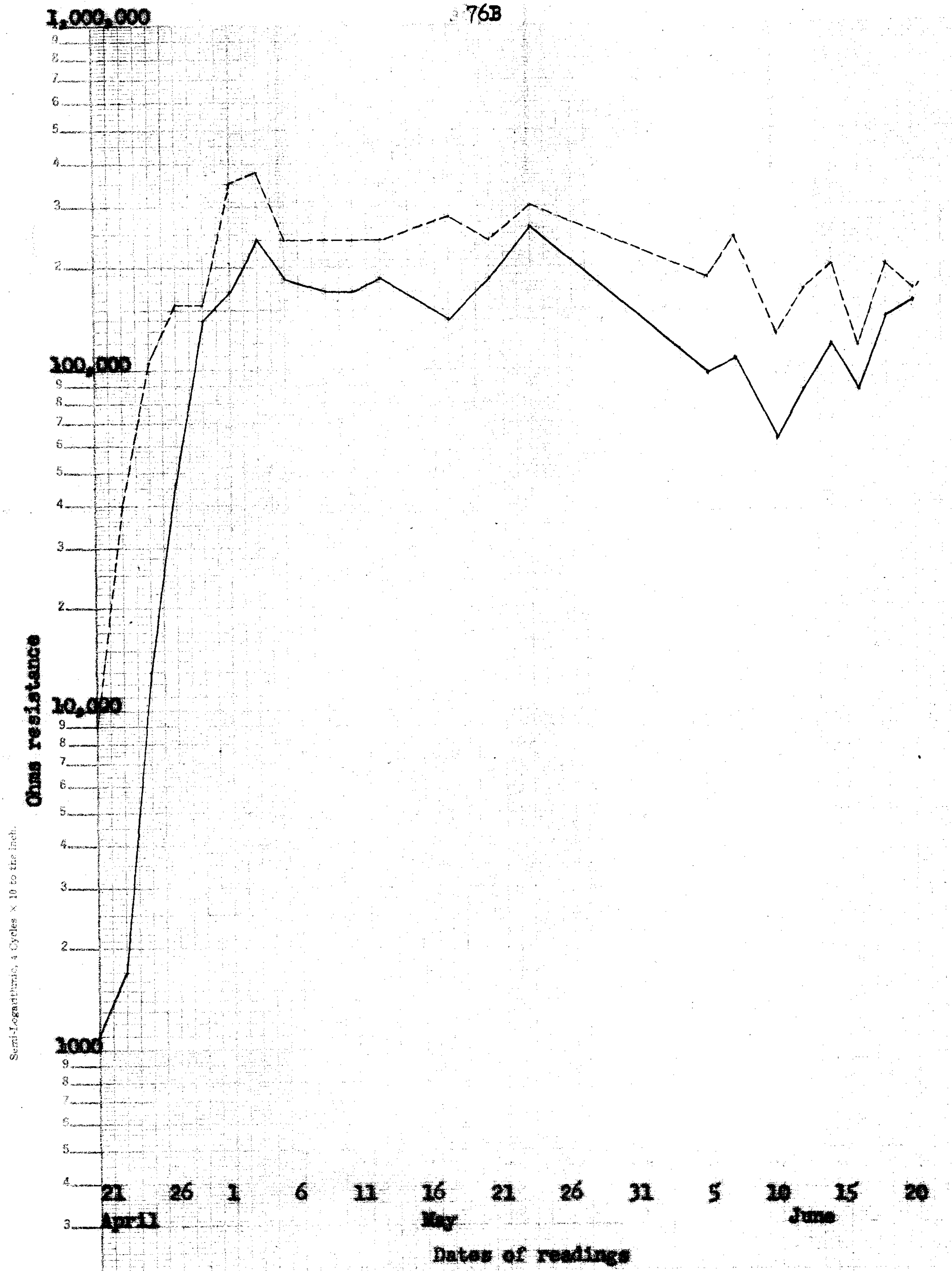


Figure 7. Seasonal moisture tensions as influenced by seeding combinations of alfalfa and orchard grass planted in rows spaced six inches. (No partitions)

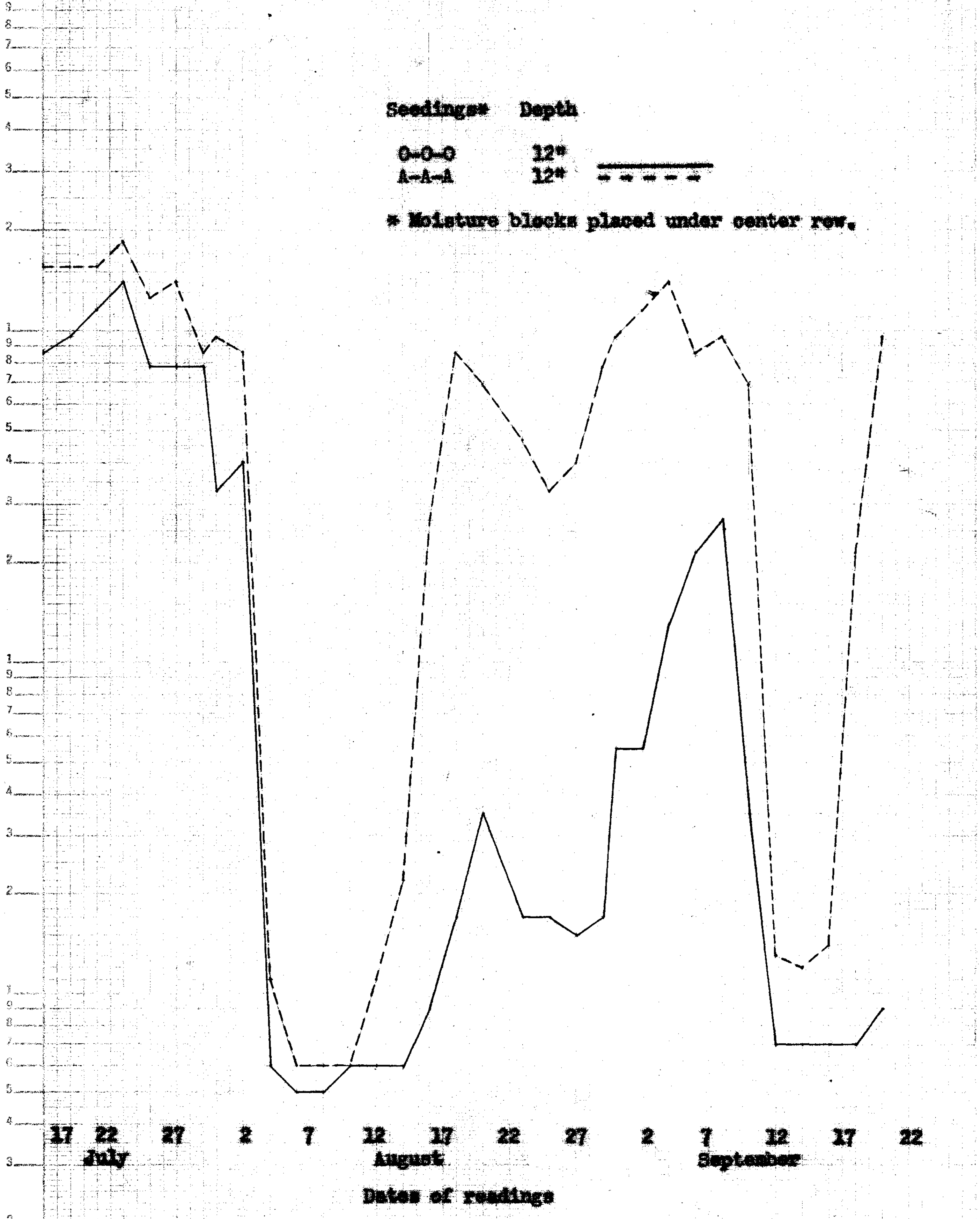


Figure 7 (Continued).

Figure 8. Seasonal moisture tensions as influenced by seeding combinations of alfalfa and orchard grass planted in rows spaced six inches. (No partitions)

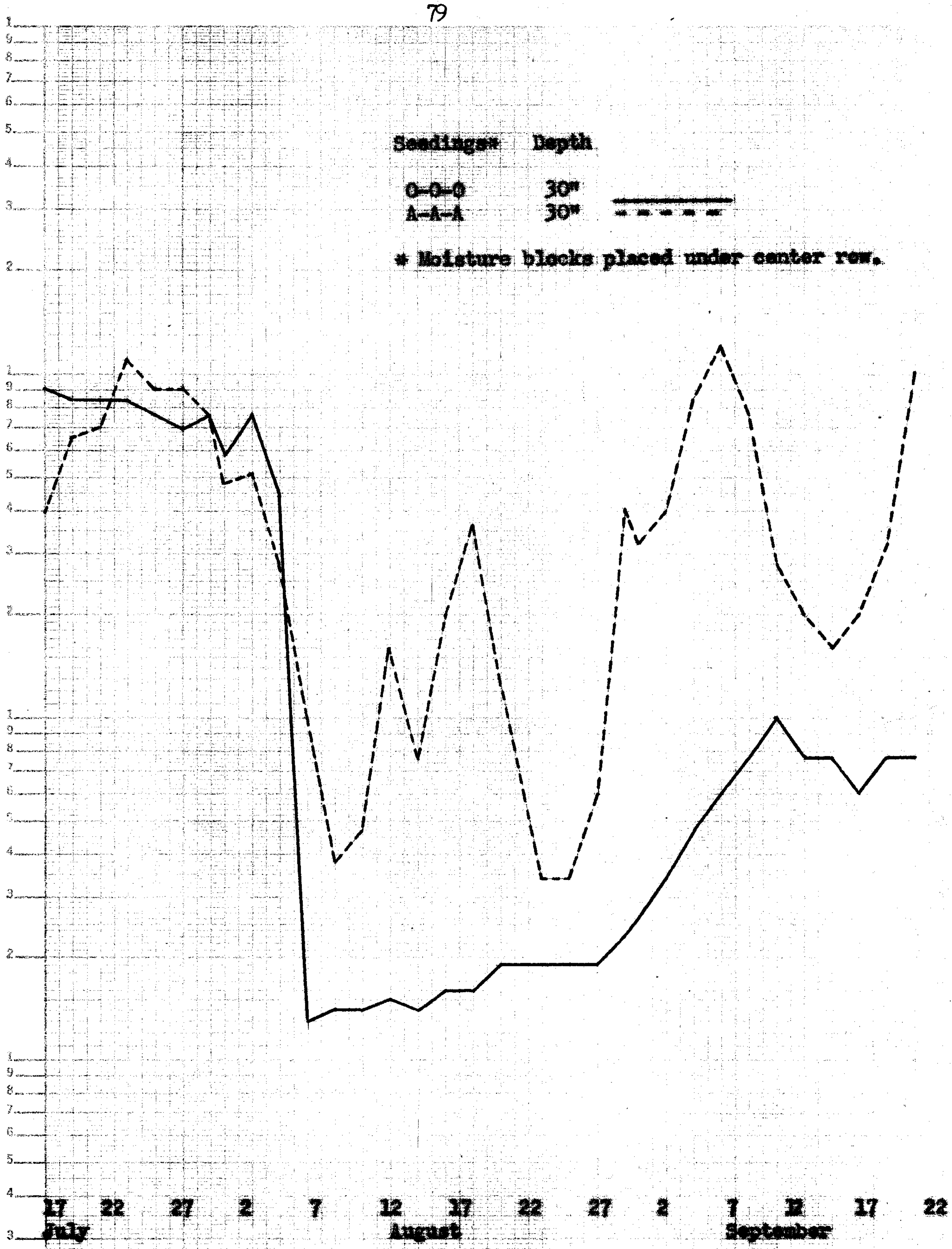


Figure 8 (Continued).

much more moisture from the lower depths than did orchard grass. As the growth of orchard grass decreased during summer and fall, greater differences in moisture usage were evident.

In Figures 9 and 10, the moisture tensions at various depths under orchard grass and alfalfa, respectively, are compared. The greatest fluctuation in soil moisture occurred at the 3-inch depth and the least at the 30-inch depth. As previously shown, the 12-inch zone was the driest zone under both orchard and alfalfa during most of the season.

In general, there was a gradual lowering of block resistances at the lower depths after rains. The block resistance did not fall immediately to the field capacity level; in fact, in most cases the blocks did not drop to 1000 ohms after the rains. The reason for this phenomenon is not clear. The blocks did not often reach tensions of 1000 ohms at the upper levels. There was a lag in the time required for the blocks to reach equilibrium with the soil moisture, and rapidly transpiring alfalfa plants dried the soil before the blocks reached equilibrium with the soil at its wettest point. Alfalfa dried the soil from near field capacity to wilting very rapidly (Figures 6, 7 and 8). The soil was dried more rapidly at the 3-inch level, after wetting, than at the lower depths.

Subsequent to July 13, a total of 4.50 inches of rain fell during the remainder of the month. Resistance readings of approximately 2000 ohms or less were obtained under alfalfa

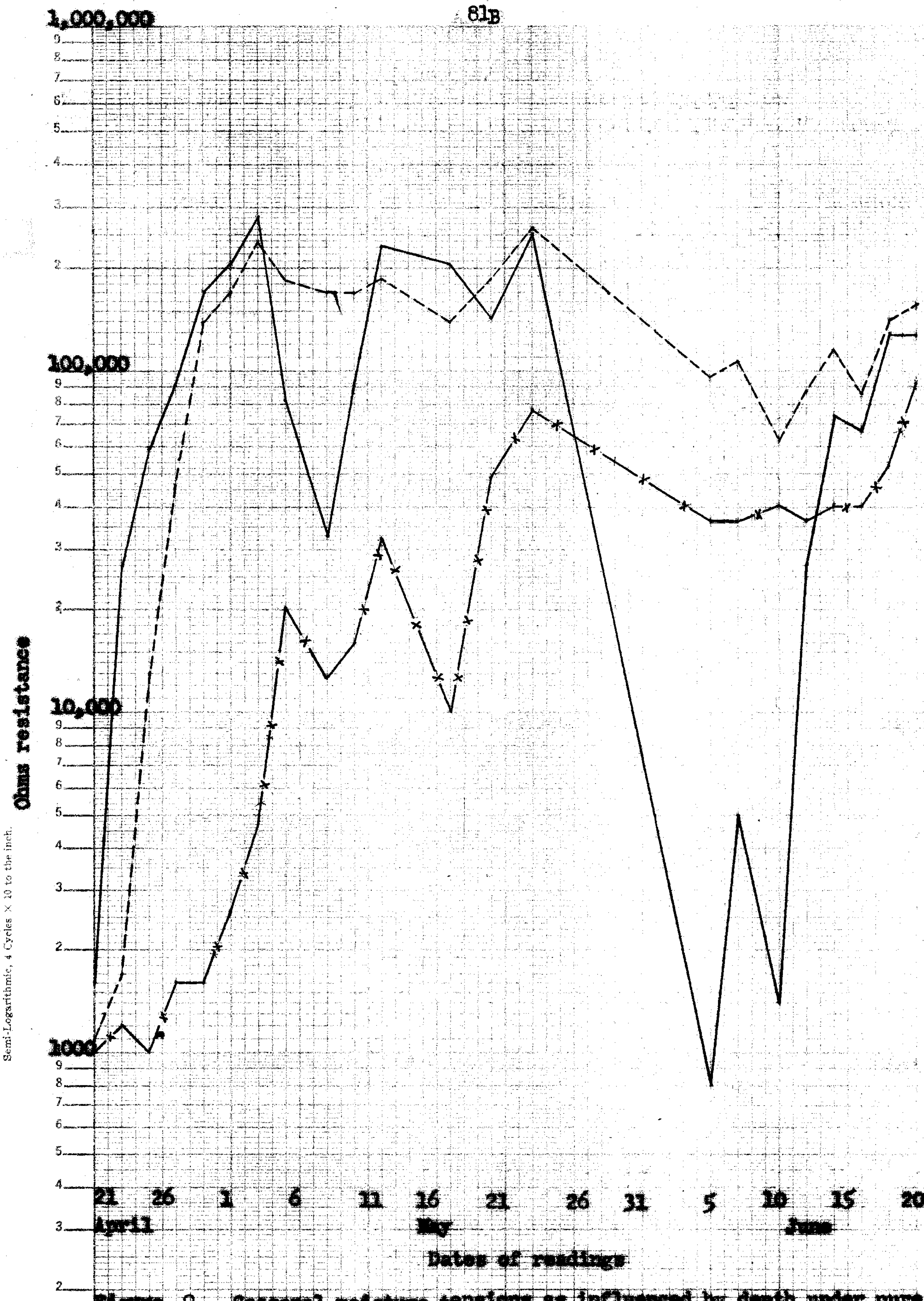


Figure 9. Seasonal moisture tensions as influenced by depth under pure stands of orchard grass planted in rows spaced six inches. (No partitions)

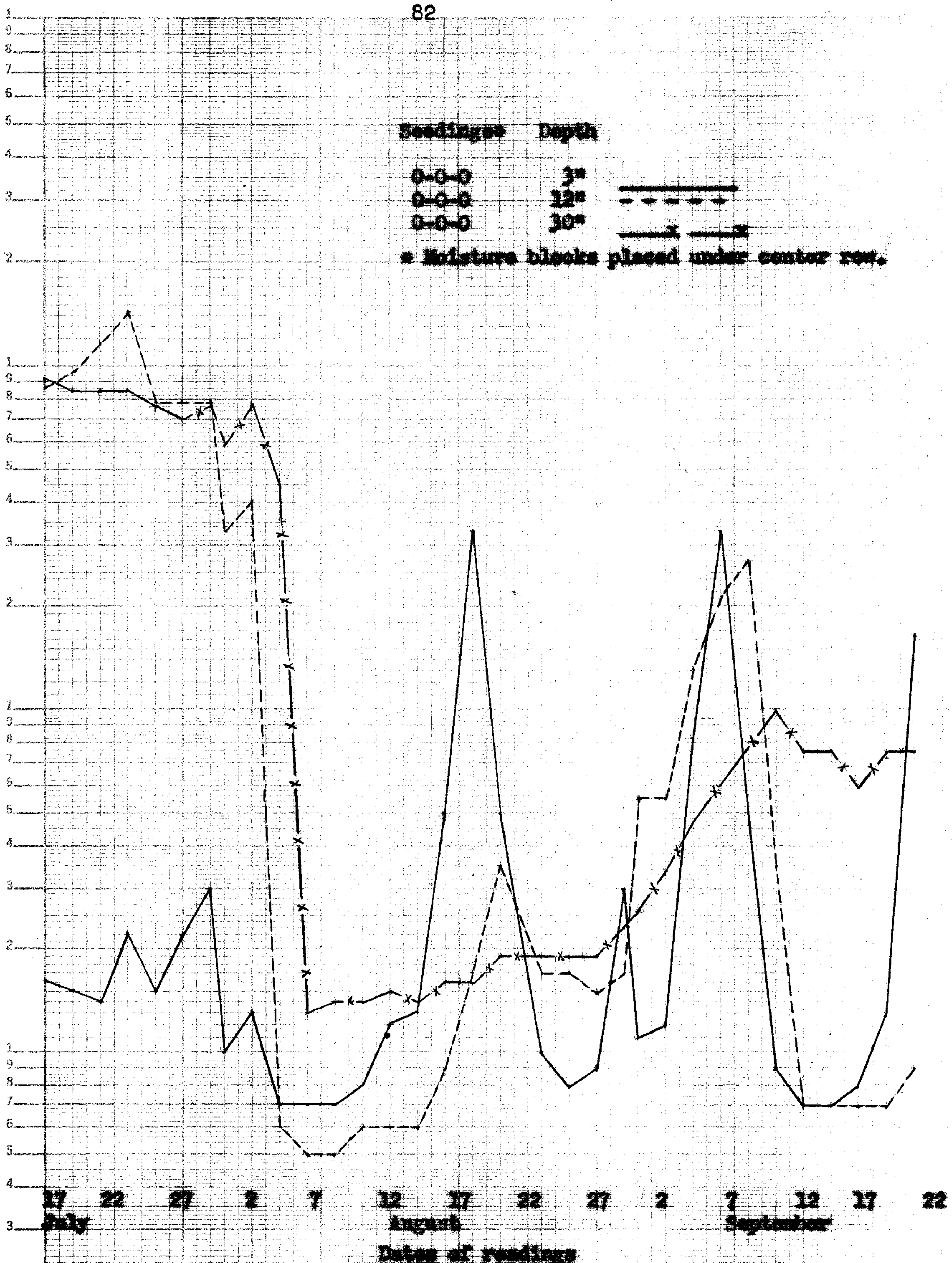


Figure 9 (Continued).

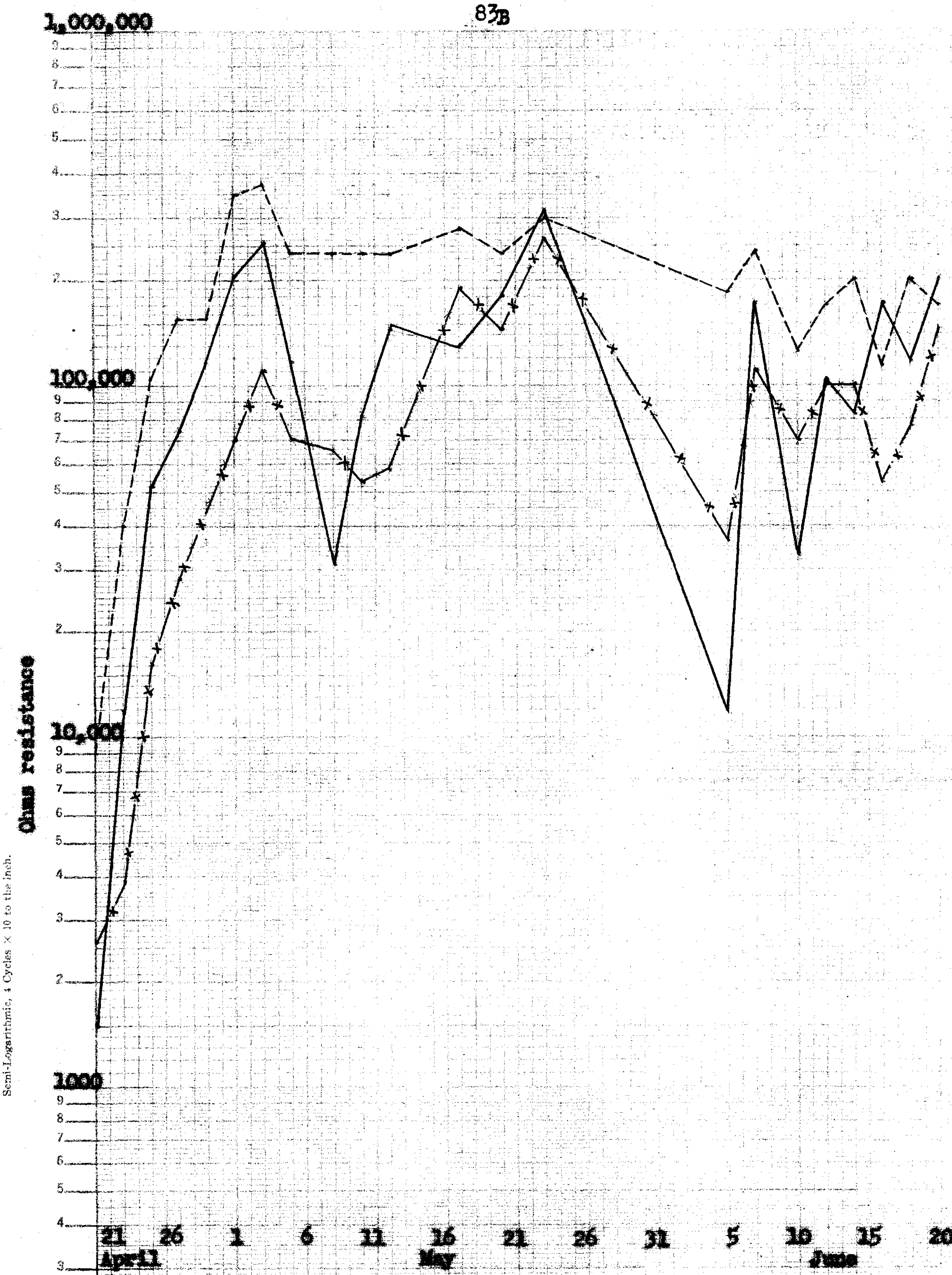


Figure 10. Seasonal moisture tensions as influenced by depth under pure stands of alfalfa planted in rows spaced six inches. (No partitions)

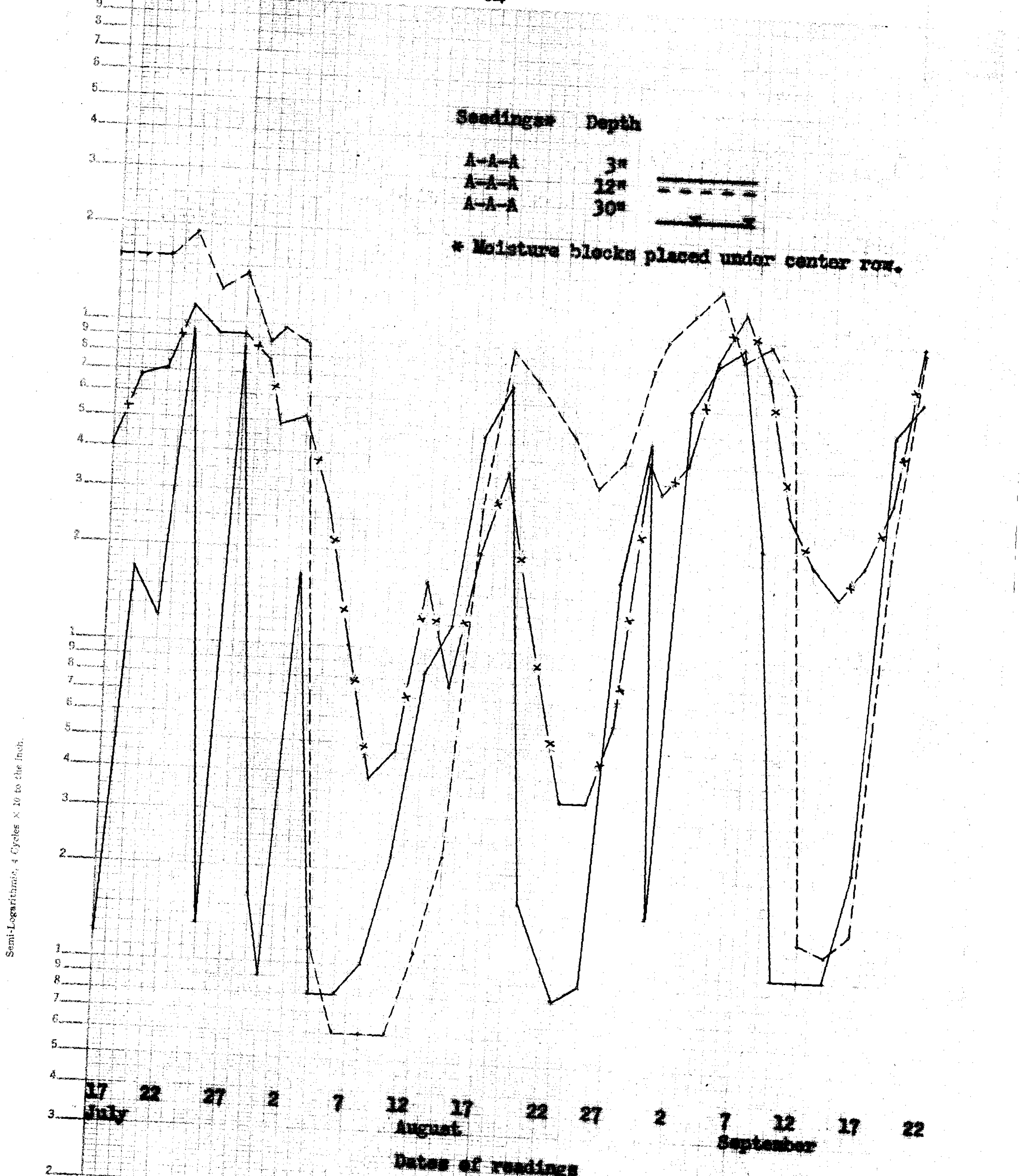


Figure 10 (Continued).

at 3, 6, 12, 24, and 30 inches on the following dates, respectively, July 17, July 30, August 4, August 8, and August 8. It is believed that the soil was moistened to a tension of 2000 ohms or less before these dates, but that the alfalfa removed the water before equilibrium with the blocks could be reached.

Alternate row relationships (ohms resistance). A comparison of O-O-O and A-O-A seeding combinations at the 3 and 12-inch levels are graphically plotted in Figures 11 and 12 for the nonpartitioned blocks. The blocks were located under the center row of the above mentioned combinations. During April and May, orchard grass and alfalfa produced approximately the same amount of growth, and there was a similar rate of removal of soil moisture under rows of orchard grass, bordered by either orchard grass rows or alfalfa rows. During August and September, however, alfalfa produced much more growth than orchard grass. Throughout this period, alfalfa removed considerably more soil moisture under the orchard grass rows than did adjacent rows of orchard grass. It was evident that alfalfa can remove soil moisture, even at the 3-inch depth, as rapidly as orchard grass.

Yield data showed that alfalfa rows bordered by orchard grass (O-A-O) produced considerably more forage than did alfalfa rows bordered by alfalfa (A-A-A). During the latter part of the season similar moisture tensions were obtained under treatments O-A-O and A-A-A. This similarity in moisture

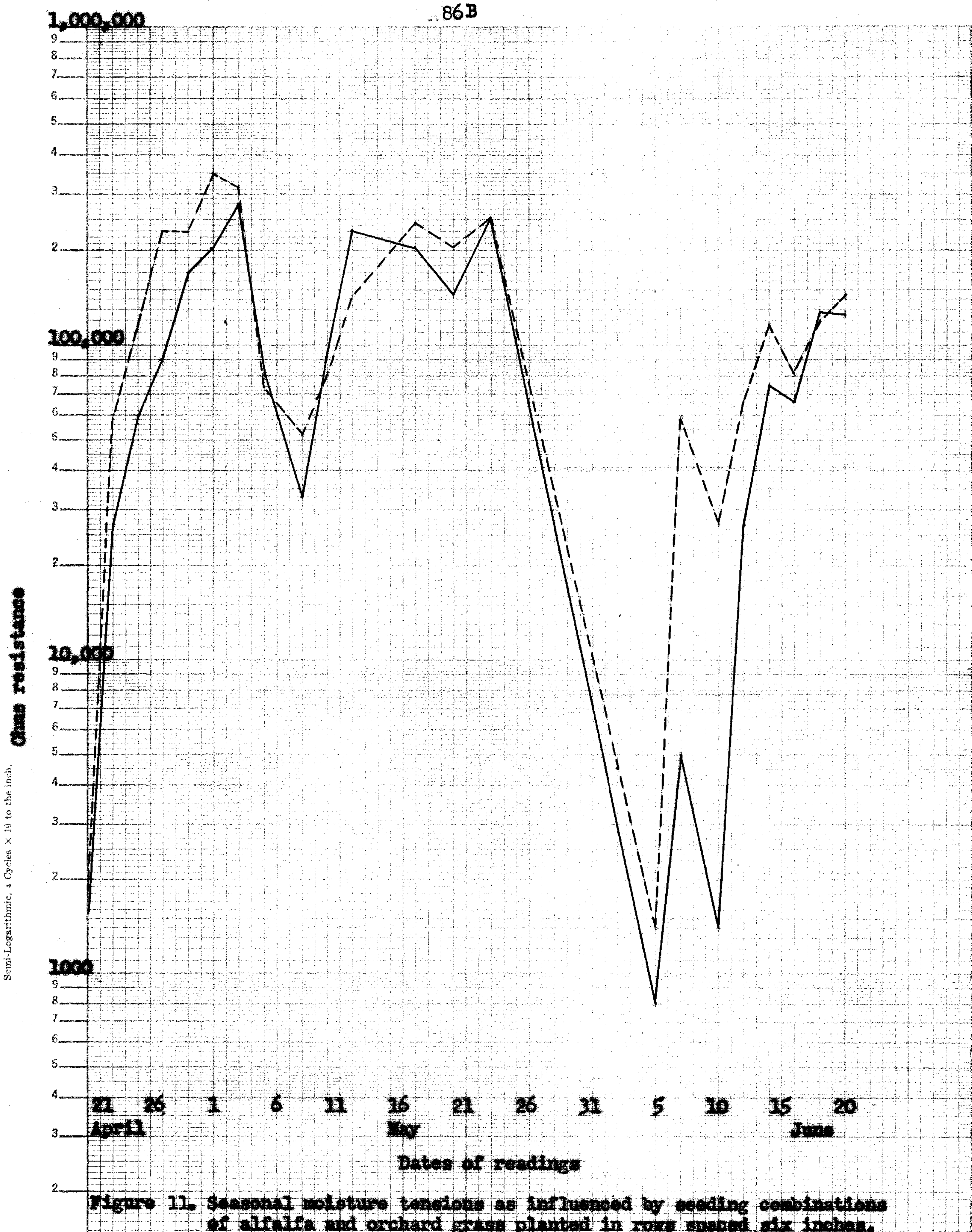


Figure 11. Seasonal moisture tensions as influenced by seeding combinations of alfalfa and orchard grass planted in rows spaced six inches. (No partitions)

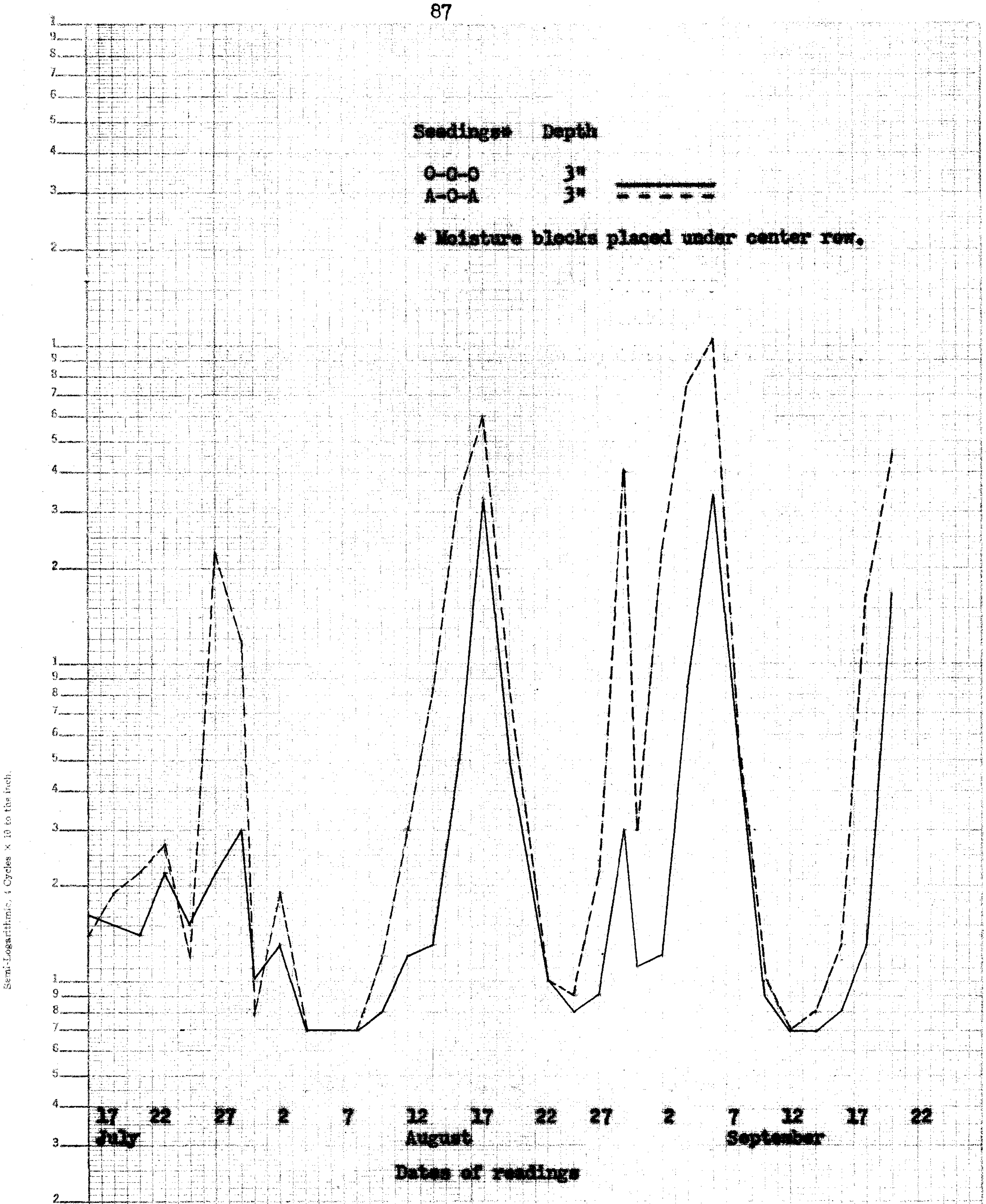


Figure 11 (Continued).

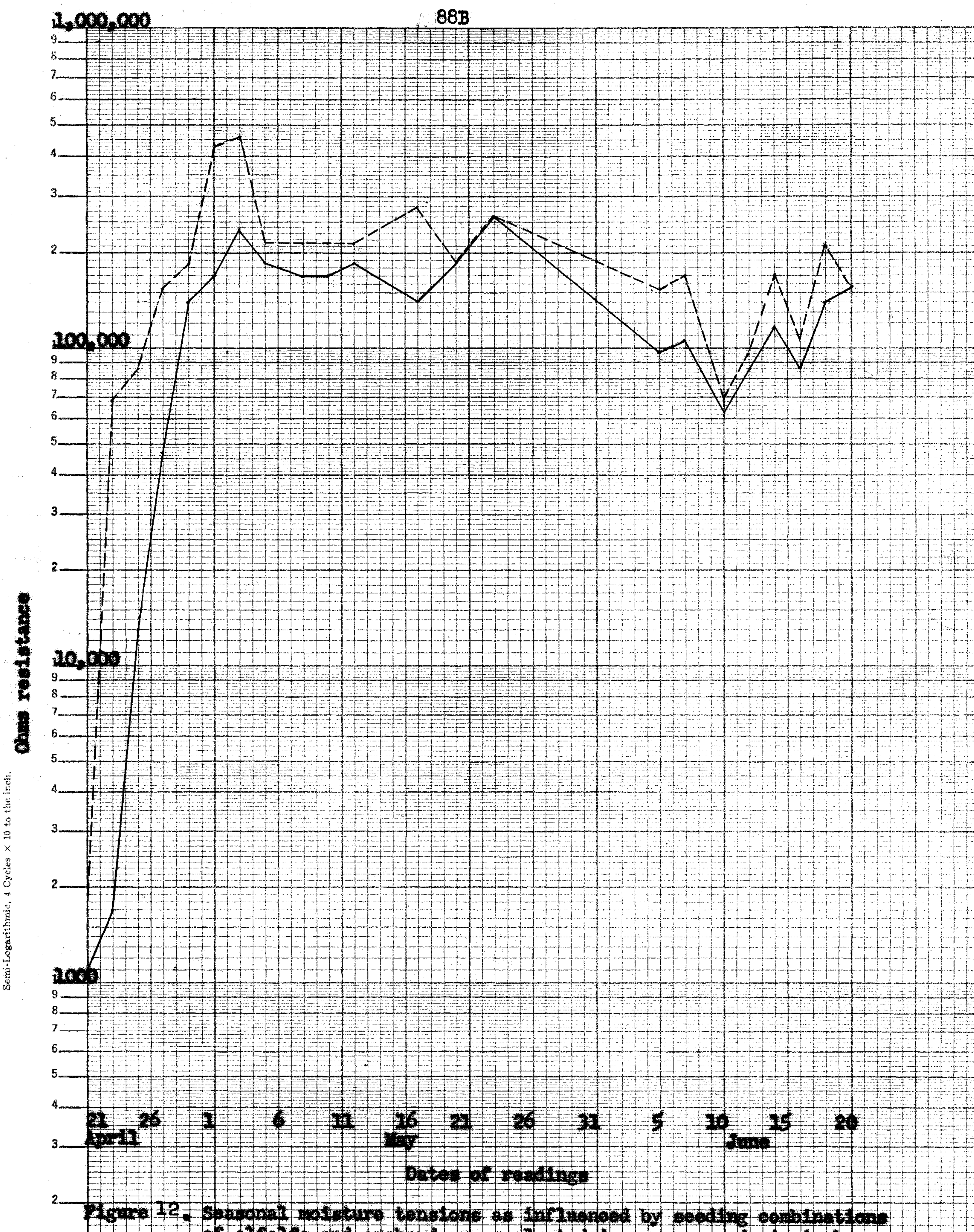


Figure 12. Seasonal moisture tensions as influenced by seeding combinations of alfalfa and orchard grass planted in rows spaced six inches. (No partitions)

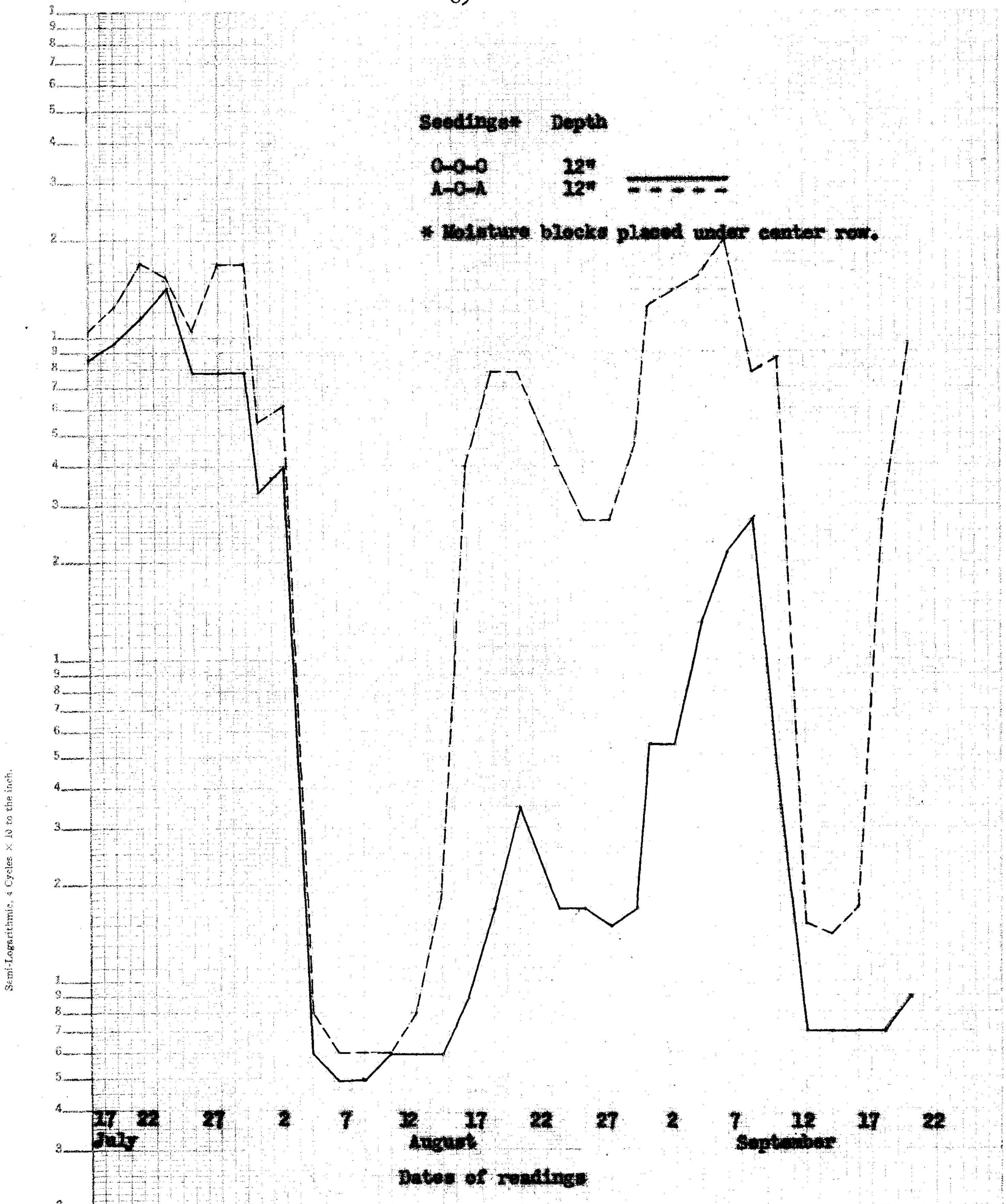


Figure 12 (Continued).

tensions was partially a result of the increased growth of alfalfa in alternate row planting.

Partitioned versus nonpartitioned (ohms resistance). Comparisons between orchard grass rows and alfalfa rows within the partitioned block, Table 3 (Appendix), further substantiated the fact that alfalfa removed soil moisture at all depths more rapidly than did orchard grass during most of the season. The differences were larger at the lower depths and during summer and fall.

In treatment O-A-O, blocks under the alfalfa rows at 3, 6 and 12 inches dried at approximately the same rates under the partitioned as under the nonpartitioned row. The sheet metal barriers restricted the lateral spread of the alfalfa roots and caused higher than normal resistance readings under the alfalfa rows.

In Figures 13 and 14 are plotted the moisture tensions obtained under a row of orchard grass, with and without metal barriers separating it from rows of alfalfa. It was obvious that alfalfa on the nonpartitioned blocks drew heavily from the soil moisture present under the orchard grass row.

Soil moisture per cent. The soil moisture present under the different seeding combinations at various depths are given in per cent in Tables 4 and 5 of the Appendix. These data are averages of five replications. The resistances in ohms

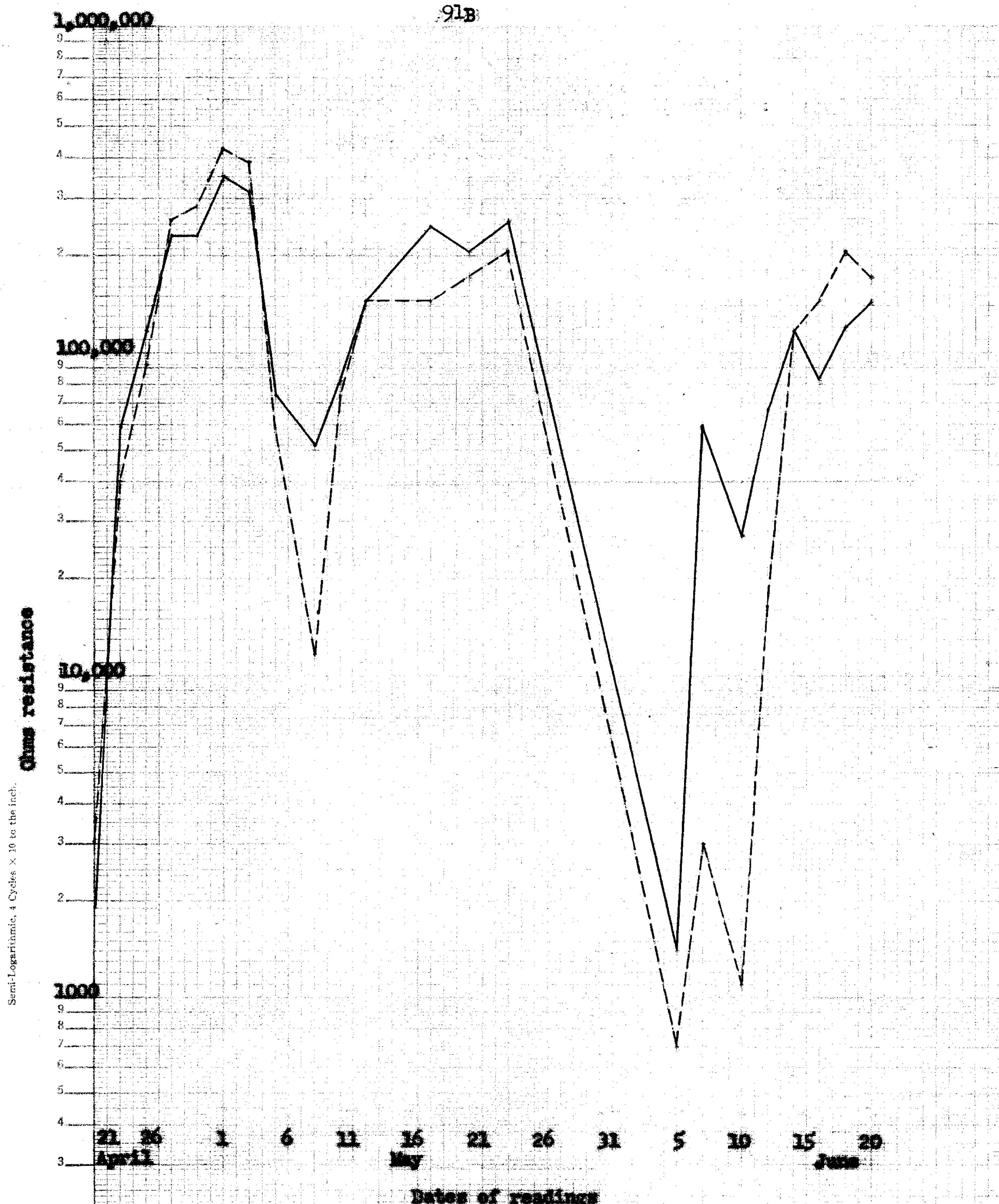


Figure 13. Seasonal moisture tensions as influenced by seeding combinations of alfalfa and orchard grass planted in rows spaced six inches. (Partition vs. no partition)

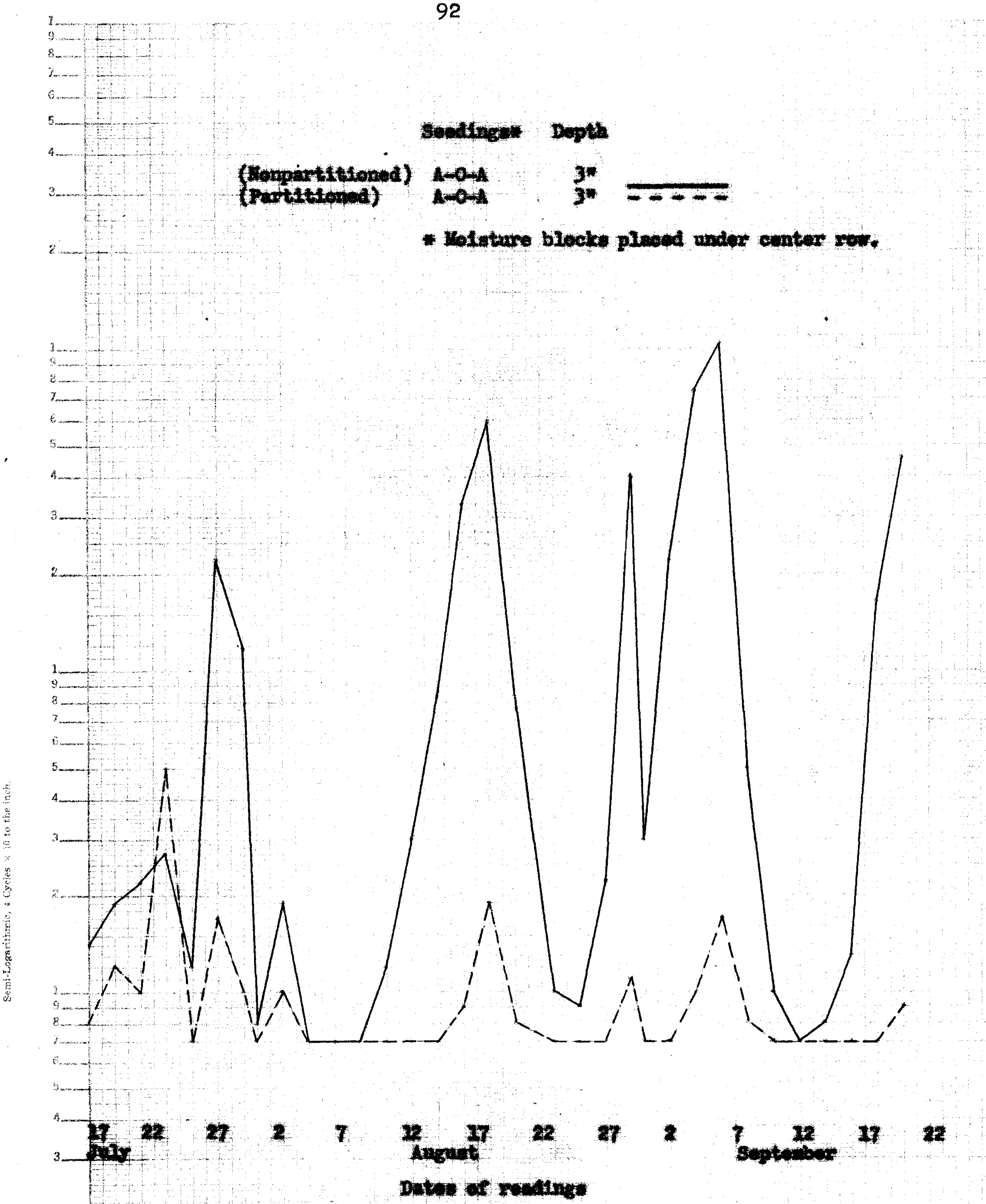


Figure 13 (Continued).

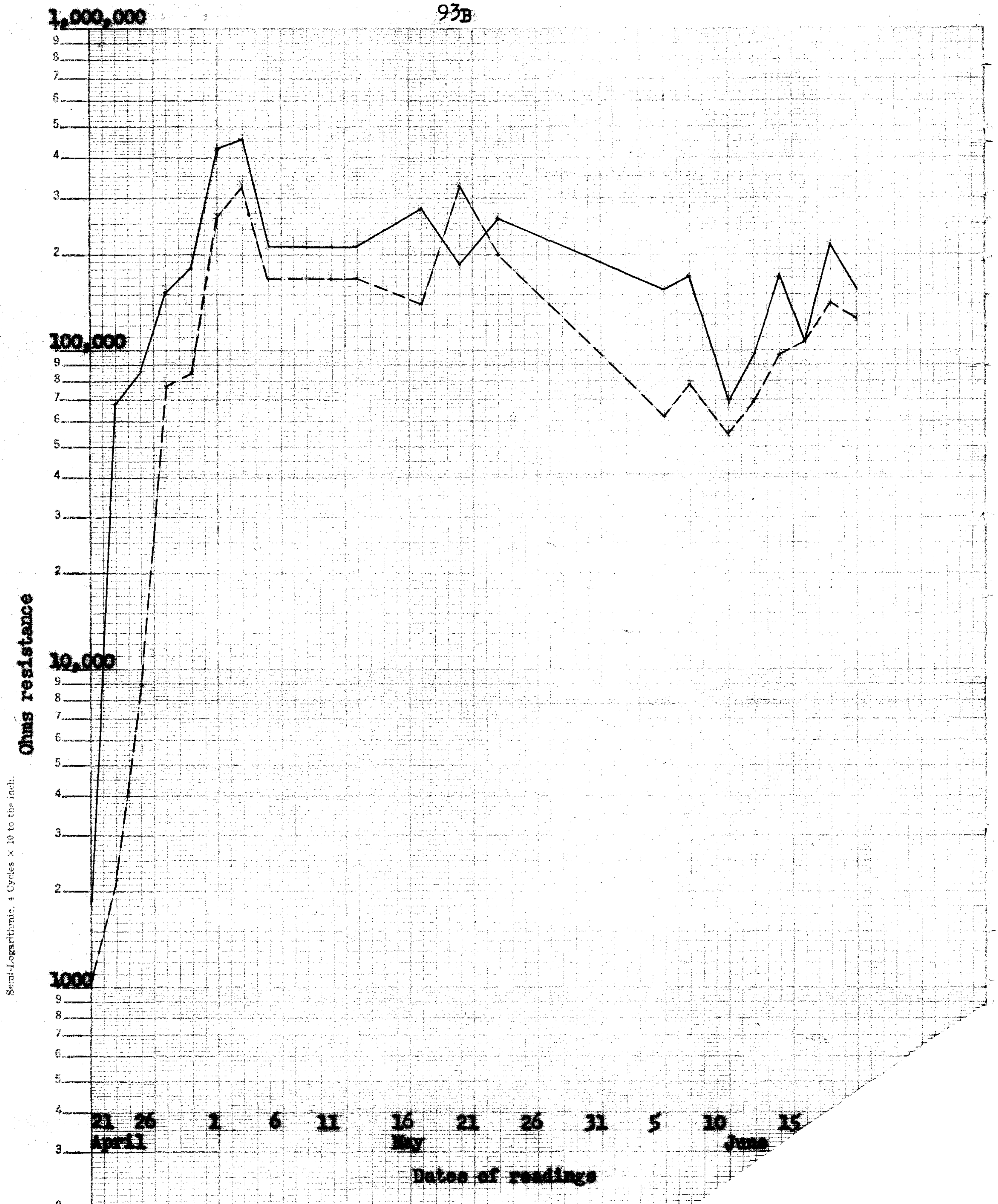


Figure 14. Seasonal moisture tensions as influenced by
of alfalfa and orchard grass planted in
(Partition vs. no partit

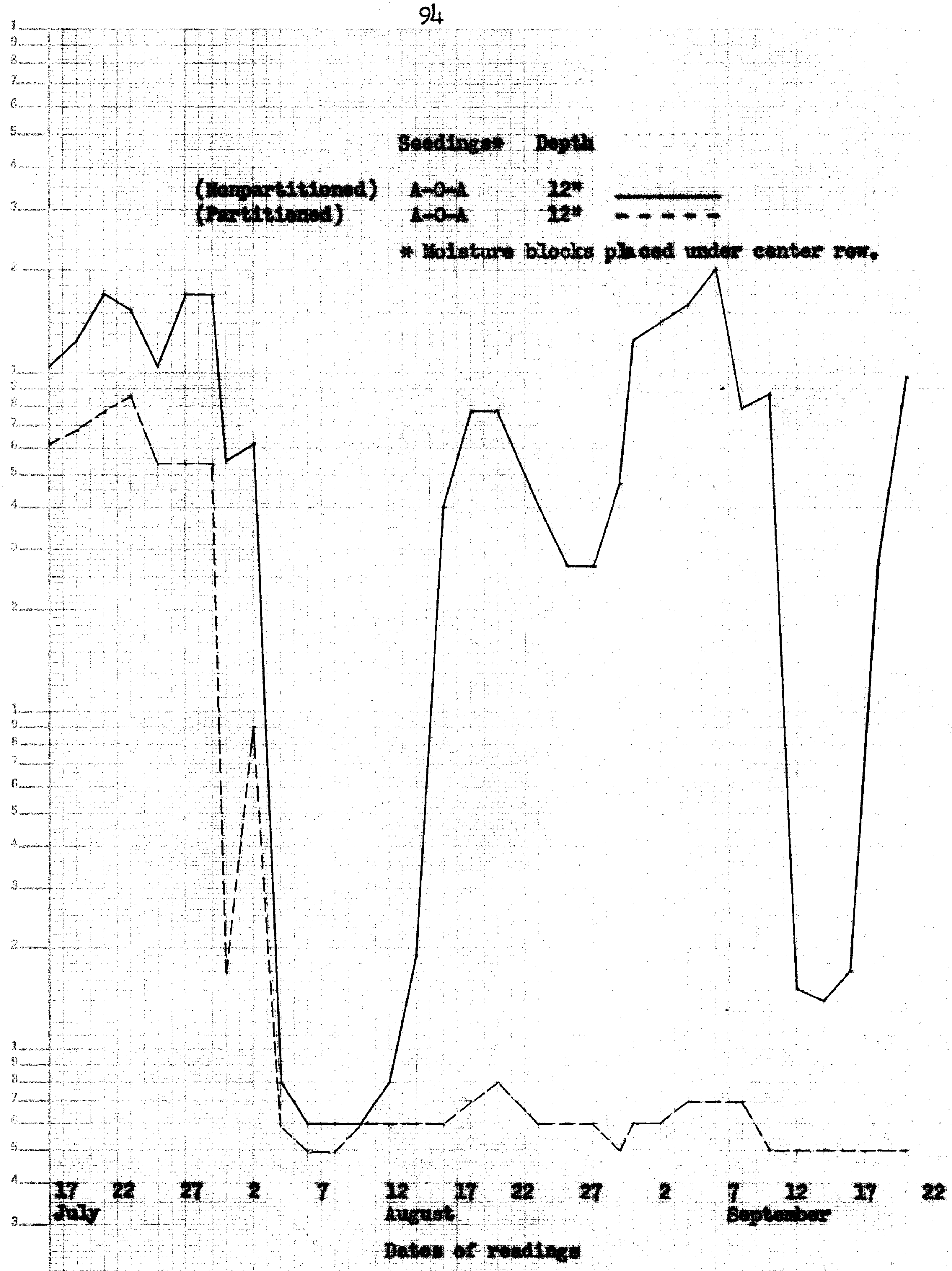


Figure 14 (Continued).

represented by these percentages are shown in Tables 2 and 3 of the Appendix. Comparisons between seeding combinations can readily be made at any specific depth; however, comparisons in percentage moisture between depths are difficult to interpret. Since the permanent wilting percentage of the soil from 0-6 inches was 5.4 per cent and the wilting percentage of the soil at 24-30 inches 20.1 per cent moisture, it was difficult to compare moisture between depths in per cent. Resistances in ohms afford a better method of expressing moisture stress in the soil.

DISCUSSION

Experiment A

It is generally recognized that much lower seeding rates could be recommended, if better seedbeds were prepared and proper covering practiced. For example, under optimum soil and weather conditions, a 5-pound rate of alfalfa may provide as many established plants per acre as a 25-pound rate seeded under adverse conditions.

Stand counts made in Virginia (35), one year after seeding, showed approximately 23 alfalfa plants per square yard in an area seeded at 20 pounds per acre. Studies in North Carolina (66) showed 250 plants present per square yard ten months following seeding at a similar rate on Cecil sandy clay loam. There is, undoubtedly, an optimum number of plants necessary for maximum yield on any particular soil type, with a given climatic condition.

In the experiment reported herein good stands were obtained of all species. An average of over 600 plants per square yard were present in the plots a few weeks after seeding. Stand counts, three weeks following seeding, showed that the seedlings were established in proportion to the rate of seeding. Reductions in total yields of the mixtures were obtained from plots which received a high seeding rate of grass; yet, botanical separations in the spring and summer showed no greater quantity of grass present in plots receiving the higher rate of grass. There was less alfalfa present in these plots. It was evident that the alfalfa stands were weakened prior to the first harvest dates. Excessive numbers of grass seedlings apparently competed very strongly with alfalfa in the first few months following seeding, and probably reduced the number of alfalfa seedlings to less than optimum for the available land area. The magnitude of the reduction in total yield resulting from high seeding rates of grass was much greater the first year after seeding than in the second year. The root systems of the sparsely placed plants were more developed in the second year, and capable of utilizing the available soil area.

The effect of method of seeding on initial establishment cannot be determined by a single experiment. Broadcasting, drilling, or alternate row seedings may appear to be the superior method, dependent upon the particular climatic conditions prevailing immediately following seeding.

In this experiment there was little difference in the initial establishment of the various species seeded by different methods. Excellent stands were obtained by all methods. In the broadcast plots the individual alfalfa and grass plants were spaced at the maximum distance as regards surface area. In alternate row plots the individual species were in much greater competition with themselves and were not uniformly spaced over the available land area. The closest association between species was obtained in the mixed in the row plots.

Alternate row spacing of alfalfa and grass was inferior to the other methods. The fact that alfalfa produced less growth in alternate rows may be partially attributed to the increased competition due to the greater growth of grass in alternate rows and partially to lack of optimum spacing. Tall fescue was favored more by alternate row planting than was orchard grass. Alternate planting exposed the grass rows more directly to the sunlight than did broadcast or drilled seedings. Brown (11) showed that 70° F. was optimum temperature for growth of orchard grass. Therefore, in alternate rows, orchard grass may have been retarded somewhat in growth by excessive temperatures. Although no differences in total yields were obtained between the broadcast and mixed in the row methods of seeding, alfalfa produced slightly more growth in the broadcast plots than in the mixed in the row plots. The grass evidently offered greater competition to the alfalfa when planted in rows than when broadcast. If, under all conditions encountered in the field, broadcast seedings gave equal establishment to mixed in the row (drilled), it may be preferable to broadcast alfalfa-grass mixtures. However, as yet there is little evidence to justify broadcasting as a superior method of seeding.

Although there were no differences in total yield between alfalfa-tall fescue and alfalfa-orchard grass in the two years' data reported, tall fescue tended to be more suppressive to alfalfa growth than orchard grass. After four or five years lower total yields may be realized from the alfalfa-tall fescue plots.

Tall fescue commenced growth two or three weeks earlier in the spring than orchard grass, but by the first harvest, usually in May, orchard grass produced almost as much forage as tall fescue. During the summer months orchard grass produced more growth than tall fescue.

Experiment B

Tall fescue produced more forage in widely spaced than in narrowly spaced rows. Orchard grass, however, produced much less forage per acre when planted in widely spaced rows. The shading effect of alfalfa probably contributed materially to the increased growth of orchard in narrow rows.

Tall fescue produced slightly less forage than orchard grass in six inch spacings with alfalfa; however, the growth of alfalfa was suppressed to the greatest extent in the alfalfa-fescue mixture. Similar evidence was presented in Experiment A.

In 1948, the alfalfa-orchard grass mixture produced more total forage than the alfalfa-fescue mixture in narrowly spaced rows. In widely spaced rows, alfalfa-fescue produced more forage than the mixture of alfalfa and orchard grass. The production of these mixtures was dependent upon method of seeding. Some pasture workers plant mixtures in alternate rows in order to facilitate botanical separation. It was evident that differences in row width may substantially affect the growth of the species evaluated.

Weeds were much more numerous in the widely spaced rows. They were removed by hand in this experiment.

Experiment C

Yields

In the first year, orchard grass produced more growth when grown between two rows of alfalfa than when grown between two rows of orchard grass. The magnitude of the increase was similar in partitioned and nonpartitioned plots. Consequently, this increased growth can not be attributed to nitrogen excretion or sloughing of nodules in 1947.

Brown (11) has shown that 70° F. is the optimum temperature for growth of orchard grass. The increased growth obtained from orchard grass, during the first year of Experiment C, largely arose from an above ground effect. The large canopy of alfalfa growth probably reduced the air and soil temperature to more nearly the optimum for orchard grass growth.

In the spring of the second year, 1949, there was some evidence of nitrogen excretion or sloughing of nodules. Orchard grass, in April, 1949, produced more growth when grown between two rows of alfalfa (A-O-A) than when grown between two rows of orchard grass (O-O-O). The magnitude of the increase was considerably larger in nonpartitioned plots than in partitioned plots. As shown by Wilson (73) long days and cool temperatures favor excretion. Previous observations in North Carolina had shown a marked increase in the growth of grasses in early spring when grown with legumes. It is postulated that in the first year most of the sugar supply was used in growth of the alfalfa plants. In the early spring of the second year, with longer days and low temperature, growth was slower and excess sugars were produced which the nodules used to produce more growth. As a result, more nitrogen was fixed.

There was direct evidence of above and below ground competition between alfalfa plants for the various growth factors. Alfalfa produced more growth when grown between two orchard grass rows (O-A-O) than when grown between two alfalfa rows (A-A-A), in partitioned and nonpartitioned plots. Orchard grass was not as competitive for growth factors as alfalfa, above or below ground. Light and soil moisture possibly limited growth most frequently.

It is believed that if alfalfa is properly managed and fertilized, it can compete successfully with orchard grass for soil moisture and nutrients. Diseases of alfalfa hasten the shift of dominance to grass in many areas. Although many alfalfa diseases are prevalent in the Southeast, none as severe as bacterial wilt have invaded this area. Results of this experiment, and other observations, indicate that alfalfa can be maintained as the dominant species in an alfalfa-orchard grass mixture for several years in this region.

The low nitrogen content of the soils in the Southeast retards rapid growth and development of grasses. For this reason, grasses grown with legumes in this region can not be expected to be as aggressive as on soils with a higher nitrogen content. Diseases of orchard grass, several of which are unidentified, also prevent orchard grass from quickly gaining dominance in grass-legume mixtures throughout North Carolina.

<u>Soil moisture</u>

Resistance readings of approximately 500,000 to 800,000 ohms were calculated as the permanent wilting tensions for the different layers of soil. Bouyoucos and Mick (9) arbitrarily used 75,000 ohms as an indicator of the wilting percentage. They postulated, however, that 1,000,000 ohms may be a better index. In all soil layers calibrated in this experiment only

2.5 to 3.0 per cent of water was present between tensions of 75,000 and 800,000 ohms. Studies in California (50) with an Altamount clay loam, showed that approximately 3 per cent of soil moisture was present between first permanent wilting and ultimate wilting. Studies with several other soils showed similar ranges of soil moisture between these two points.

Even during severe drought, readings of 800,000 ohms or higher were rarely obtained in the field during the study reported herein. It was evident that moisture was severely limiting plant growth at a much lower tension.

The Bouyoucos blocks seemed well adapted to measure changes in soil moisture from the wilting percentage to near field capacity. A reading of approximately 600 ohms resistance was considered as approximating field capacity conditions, according to Bouyoucos and Mick (9). In the laboratory, resistances of 600 ohms or less were easily obtained by saturating the soil and allowing it to drain. Resistances as low as 600 ohms were rarely obtained under field conditions. Light showers following droughts did not often wet the blocks to resistances of 600 ohms. According to Colman (14), studies with mountain soils in California indicated that the soil must be wetted to 12 to 30 inches before the surface layer will have attained a moisture content as high as normal field capacity. This fact and the postulation that alfalfa and orchard grass removed the water before equilibrium with the blocks could be reached probably accounts for the relatively high resistance readings obtained following light showers.

These studies indicate that moisture is frequently a limiting factor in the growth of alfalfa in North Carolina. On 58 per cent of the reading dates, resistances higher than 10,000 ohms were obtained at 3, 6, 12, 24 and 30 -inch levels under alfalfa. On 22 per cent of the reading dates, the soil was drier than 75,000 ohms at these depths. The root systems of alfalfa penetrated to a maximum depth of 36 inches in this soil. It was evident that moisture was rapidly utilized by the growing alfalfa plants. There was a period of approximately 30 days during the summer of 1948 when growth practically ceased because of insufficient available moisture. Moisture readings were temporarily discontinued. Although North Carolina has an annual rainfall of approximately 50 inches, there are many periods during the growing season when the moisture supply becomes the limiting growth factor.

Studies in Michigan (9) showed that the most practical time to apply irrigation water to growing plants was when the block resistances reached or slightly exceeded 10,000 ohms. Alfalfa removed soil moisture very quickly to this resistance in the study reported in this manuscript. Irrigation of pastures and forage crops is currently practiced on a limited scale by farmers in the Southeast. This study indicated that moisture may frequently become insufficient for maximum alfalfa growth throughout the zone of root penetration, on a Cecil sandy clay loam.

It was evident from this study that alfalfa used soil moisture at the 3, 6 and 12-inch levels as or more rapidly than orchard grass. At the lower depths, the soil was dried more rapidly by alfalfa than by orchard grass.

The roots of alfalfa and orchard grass permeated the soil to a maximum depth of 36 inches (Figure 5). The alfalfa roots were well distributed downward to 36 inches; whereas, a large proportion of the orchard grass roots were located in the upper 12 inches. Alfalfa removed the soil moisture at all depths as rapidly or more rapidly than orchard grass; consequently, alfalfa may be expected to maintain itself, in association with orchard grass, for several years.

SUMMARY

Experiment A

Experimental plots for the investigation of alfalfa-grass mixtures were located on a Cecil sandy clay loam near Raleigh, North Carolina. In Experiment A, 5 rates and 3 methods of seeding alfalfa-orchard grass and alfalfa-tall fescue were studied. Rates of seeding ranging from 10 to 20 pounds of alfalfa, and 5 to 15 pounds of grass were evaluated. Comparisons were made between alternate row, mixed in the row, and broadcast methods of seeding. The spacing between rows was 6 inches. The plots were seeded August 31, 1946, and the data reported were obtained in 1947 and 1948. Nine harvests were made during the 2 years, and botanical analyses of all treatments were determined twice annually. The forage from certain treatments was analyzed for nitrogen content. Summary follows:

1. An average of all methods and rates of seeding for the two years showed no differences in total yield between alfalfa-orchard grass and alfalfa-tall fescue. Combined statistical analyses of the total yields produced in the two years showed no interactions between treatments.

2. In the first year, reductions in total yields were obtained from plots receiving a high seeding rate of grass, and those receiving a low seeding rate of alfalfa.

3. In the second year, there were significant differences in total yields between methods of seeding. The alternate row plots produced less forage than the broadcast or mixed in the row plots. The mixed in the row plots of alfalfa-fescue tended to produce less forage than the broadcast plots.

4. Seedling counts, three weeks following seeding, showed that seedlings were present in proportion to rate of seeding.

5. Botanical separations demonstrated that less alfalfa was present in plots which received a high seeding rate of grass or less than 15 pounds of alfalfa per acre. Similar yields of grass were obtained from plots receiving high seeding rates and those receiving low seeding rates. Since lower total yields were obtained from plots receiving high seeding rates of grass, it was evident that the grass had influenced the establishment and growth of alfalfa prior to the harvest dates.

6. In the alfalfa-grass mixtures, alfalfa produced more growth in the broadcast than in the mixed in the row, or alternate row plots. The grasses, in general responded inversely.

7. Tall fescue produced more forage in early spring and fall than did orchard grass. In the summer months, the reverse was true. Tall fescue tended to suppress the growth of alfalfa more than orchard grass.

Experiment B

Alfalfa-orchard grass and alfalfa-tall fescue were seeded in narrowly and widely spaced alternate rows, 6 and 12 inches, respectively. This experiment was located adjacently to Experiment A and established on the same date, August 31, 1946. The data reported were obtained in 1947 and 1948. Summary follows:

1. In narrowly spaced (6-inches) alternate rows, the alfalfa-orchard grass mixture produced more forage than did alfalfa-tall fescue. In widely spaced (12-inches) alternate rows, the mixtures responded inversely.

2. Tall fescue was favored by wide spacing of rows; whereas, orchard grass produced considerably less forage per acre in widely spaced rows.

3. The increase in growth of the individual species, in widely spaced rows, was not sufficient to justify the wider spacing.

4. The differences in nitrogen content between tall fescue and orchard grass were not significant.

Experiment C

The site of Experiment C was adjacent to Experiments A and B. In this investigation, a study was made of some of the above and below ground relationships of alfalfa and orchard grass. The two species were grown in rows spaced at 6 inches, with and without partitioned root systems. Each species was planted in pure stands and also in alternate rows. A study of the above ground associational effects of alfalfa and orchard grass was facilitated by partitioning the root systems with sheet metal barriers. The above ground parts were allowed to intermingle, when the below ground parts were separated.

Bouyoucos' moisture blocks were installed, prior to seeding of the experiment September 1, 1947. They were placed at depths of 3, 6, 12, 24, and 30 inches, directly under variously arranged rows of alfalfa and orchard grass. Soil moisture readings were made on 55 days from April 21, 1948 to September 20, 1948. Summary follows:

1. In the first year following seeding, orchard grass was benefitted largely by its above ground association with alfalfa. In the spring of the second year, orchard grass was benefitted by both its above and below ground association with alfalfa.

2. It is postulated that air temperature was reduced to an optimum level, for growth of orchard grass, by the larger canopy of growth produced by alfalfa.

3. There was evidence of above and below ground competition between alfalfa plants for the various growth

factors. Alfalfa produced more growth when grown between two orchard grass rows than when grown between two alfalfa rows, in both partitioned and nonpartitioned plots. Orchard grass was not as competitive for the growth factors as alfalfa, above or below ground.

4. The roots of alfalfa and orchard grass permeated the soil to a maximum depth of 36 inches. The alfalfa roots were well distributed downward to 36 inches; whereas, a large proportion of the orchard grass roots were located in the upper 12 inches.

5. The Bouyoucos' moisture blocks seemed adapted to measure changes in soil moisture from the wilting percentage to near field capacity.

6. Resistance readings of 75,000 ohms have been arbitrarily used by several investigators as an indication of the wilting percentage. In this investigation, the biologically calculated permanent wilting percentages were correlated with readings of 500,000 to 800,000 ohms resistance. The corn plants used in the calibrations were severely wilted. Readings of 800,000 ohms or higher were rarely attained in the field, even during severe droughts. It was evident that moisture was severely limiting plant growth at much lower tensions. In all soil layers calibrated in this experiment only 2.5 to 3.0 per cent of water was present between tensions of 75,000 ohms and 800,000 ohms.

7. Alfalfa removed soil moisture at all depths as rapidly or more rapidly than orchard grass. During the spring months orchard grass produced approximately as much growth as alfalfa. In the upper 12 inches, the soil was almost as deficient in soil moisture under orchard grass as under alfalfa. At the lower depths, alfalfa removed soil moisture down to tensions of 75,000 ohms on several more days than did orchard grass.

8. A dryness of 75,000 ohms was obtained most frequently at the 12-inch depth, under alfalfa and orchard grass. The soil dried more rapidly at the 3-inch level, after wetting, than at lower depths.

9. On approximately 58 per cent of the reading dates, resistances higher than 10,000 ohms were obtained at the 3, 6, 12 and 30-inch levels under alfalfa. On 22 per cent of the reading dates, the soil was drier than 75,000 ohms at these depths.

CONCLUSIONS

1. Excessive numbers of grass seedlings in alfalfa-grass mixtures can reduce the growth and establishment of alfalfa prior to the first date of harvest for hay.

2. Alternate row seedings of alfalfa and grass may be expected to produce less forage than broadcast or mixed in the row seedings. Alternate row planting (6-inches) favors growth of tall fescue and orchard grass; however, growth of alfalfa is not favored by alternate planting.

3. The total yield of forage obtained from alternate rows of alfalfa-grass mixtures is dependent on width of row spacing. The highest yielding mixture under narrow row spacing may be the lowest yielding mixture under wide spacing.

4. In mixtures with alfalfa, orchard grass is benefitted by both its above and below ground associations. Alfalfa and orchard grass compete among and between themselves for the various growth factors. Under the conditions encountered in the experiment reported herein, orchard grass was not as competitive for the growth factors as alfalfa, above or below ground.

5. Alfalfa can remove soil moisture at all depths as rapidly or more rapidly than orchard grass, when equal growth is produced by each species. At the lower depths of root penetration, alfalfa removes soil moisture more rapidly than orchard grass.

6. In North Carolina, alfalfa frequently dries the soil to the wilting percentage at all depths of root penetration.

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APPENDIX

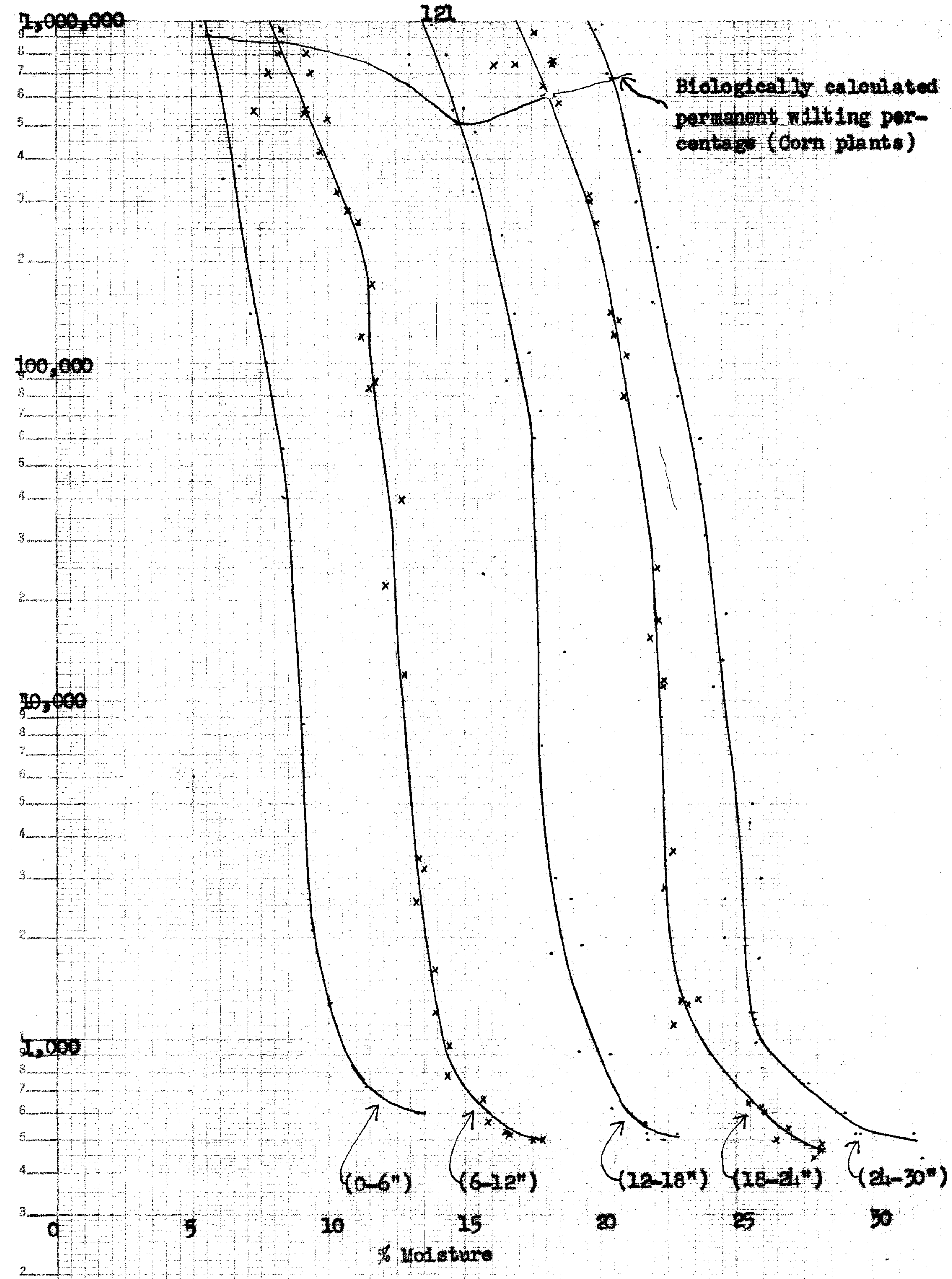

Figure 1. Calibration curves for various depths of a Cecil sandy clay loam from permanent wilting percentage to the upper range of sensitivity of Bouyoucos bridge (Experiment C).

TABLE 1. Daily distribution of rainfall in 1948 at location of Experiments A, B and C. (Wake County, North Carolina)

	Inches per day					
Date	April	May	June	July	August	September
1	0	0	0	0	0	0
2	0	.10	.75	0	1.12	0
3	0	0	0	0	.80	0
4	0	.54	.07	0	.85	0
5	0	0	0	.32	0	0
6	.57	0	0	0	0	.02
7	0	.08	.70	0	0	.57
8	.30	0	.10	0	0	.82
9	0	0	0	0	0	0
10	.27	0	0	0	0	.82
11	0	0	0	0	.30	0
12	0	.20	0	0	.03	.02
13	0	.52	0	.42	0	0
14	.80	0	.12	0	.03	0
15	0	0	0	.68	0	0
Sub-Total	1.94	1.44	1.11	1.42	3.13	2.25
16	0	0	0	.21	0	0
17	0	.40	0	0	.05	0
18	0	0	0	.41	0	0
19	0	0	0	0	.82	0
20	0	0	0	0	0	0
21	.04	0	0	.41	0	0
22	0	0	0	.11	.55	0
23	0	0	0	.83	0	0
24	0	0	0	0	0	0
25	0	.48	0	0	0	0
26	0	0	0	0	0	.04
27	0	.04	0	0	0	0
28	.08	.80	.30	.89	0	.56
29	0	.08	0	.35	.79	1.20
30	0	0	.08	.20	0	2.05
31	-	0	-	0	0	0
Sub-Total	.12	1.80	.38	3.41	2.21	3.85
Total	2.06	3.24	1.49	4.83	5.34	6.10
60 Yr. Ave. Raleigh, N.C.	3.52	3.95	4.46	5.79	5.42	3.84

TABLE 2. Moisture determinations in ohms resistance at various soil depths as influenced by pure stands and alternate spacing of alfalfa and orchard grass in rows spaced six inches. (No Partitions)

Experiment C

Seed-* ing	Depth in Inches	Thousands of ohms										
		April									May	
		21	23	25	27	29	1	3	5	8	10	12
	3	1.6	27.0	59.0	92.0	172.0	205.0	285.0	82.0	33.0	92.0	230.0
	6	1.6	8.3	43.0	88.0	185.0	330.0	355.0	250.0	150.0	165.0	270.0
0-0-0	12	1.1	1.7	13.0	47.0	140.0	170.0	240.0	185.0	170.0	170.0	185.0
	24	1.1	1.2	1.6	2.3	3.8	7.6	44.0	65.0	65.0	65.0	44.0
	30	1.0	1.2	1.0	1.6	1.6	2.6	4.7	20.0	12.5	16.0	32.0
	3	1.5	11.8	52.0	74.0	117.0	205.0	255.0	117.0	33.0	82.0	144.0
	6	3.2	18.0	75.0	102.0	250.0	270.0	330.0	150.0	88.0	117.0	165.0
A-A-A	12	9.0	40.0	105.0	155.0	155.0	350.0	375.0	240.0	240.0	240.0	240.0
	24	2.6	4.7	36.0	70.0	175.0	280.0	360.0	260.0	230.0	260.0	330.0
	30	2.6	3.8	16.0	28.0	36.0	70.0	110.0	70.0	65.0	52.5	58.0
	3	1.9	59.0	128.0	230.0	230.0	350.0	315.0	74.0	52.0	82.0	144.0
A-O-A	6	2.2	22.5	102.0	150.0	230.0	355.0	380.0	205.0	165.0	230.0	270.0
	12	1.9	69.0	86.0	155.0	185.0	430.0	460.0	215.0	215.0	215.0	215.0
	3	5.0	52.0	255.0	285.0	255.0	385.0	385.0	103.0	67.0	144.0	255.0
O-A-O	6	3.2	22.5	75.0	230.0	205.0	310.0	330.0	165.0	205.0	205.0	270.0
	12	2.6	47.0	62.0	96.0	325.0	400.0	375.0	215.0	240.0	215.0	215.0

*A-O-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 2 (Continued).

Seed-* ing	Depth in Inches	Thousands of ohms										
		May			June							
		17	20	23	5	7	10	12	14	16	18	20
0-0-0	3	205.0	144.0	255.0	.8	5.0	1.4	27.0	74.0	67.0	128.0	128.0
	6	185.0	205.0	290.0	4.6	18.0	10.3	36.0	88.0	102.0	150.0	165.0
	12	140.0	185.0	260.0	96.0	105.0	62.0	86.0	115.0	86.0	140.0	155.0
	24	70.0	110.0	160.0	91.0	120.0	84.0	100.0	110.0	91.0	120.0	145.0
	30	10.0	48.0	76.0	36.0	36.0	40.0	36.0	40.0	40.0	52.5	91.0
A-A-A	3	128.0	182.0	315.0	11.8	172.0	33.0	103.0	82.0	172.0	117.0	205.0
	6	270.0	250.0	270.0	22.5	43.0	53.0	117.0	117.0	88.0	150.0	133.0
	12	280.0	240.0	300.0	185.0	240.0	125.0	170.0	200.0	115.0	200.0	170.0
	24	260.0	230.0	280.0	175.0	230.0	120.0	145.0	160.0	91.0	160.0	175.0
	30	190.0	145.0	260.0	36.0	110.0	70.0	100.0	100.0	52.5	76.0	145.0
A-0-A	3	244.0	205.0	255.0	1.4	59.0	27.0	67.0	117.0	82.0	128.0	144.0
	6	270.0	230.0	270.0	13.5	88.0	53.0	102.0	165.0	102.0	185.0	150.0
	12	280.0	185.0	260.0	155.0	170.0	69.0	96.0	170.0	105.0	215.0	155.0
0-A-0	3	230.0	230.0	255.0	2.2	103.0	52.0	82.0	144.0	82.0	144.0	230.0
	6	230.0	205.0	250.0	43.0	102.0	53.0	88.0	150.0	88.0	133.0	150.0
	12	215.0	300.0	325.0	105.0	155.0	78.0	105.0	215.0	105.0	185.0	155.0

*A-0-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 2 (Continued).

Seed-* ing	Depth in Inches	Thousands of ohms										
		July									August	
		**	17	19	21	23	25	27	29	31	2	4
0-0-0	3		1.6	1.5	1.4	2.2	1.5	2.2	3.0	1.0	1.3	.7
	6		29.0	22.5	18.0	29.0	5.5	10.3	43.0	1.1	1.1	.7
	12		86.0	96.0	115.0	140.0	78.0	78.0	78.0	33.0	40.0	.6
	24		100.0	120.0	145.0	145.0	100.0	110.0	100.0	110.0	130.0	65.0
	30		91.0	84.0	84.0	84.0	76.0	70.0	76.0	58.0	76.0	44.0
A-A-A	3		1.2	16.5	11.8	92.0	1.3	82.0	1.6	.9	16.5	.8
	6		36.0	64.0	75.0	102.0	4.6	102.0	43.0	.7	4.6	.6
	12		155.0	155.0	155.0	185.0	125.0	140.0	86.0	96.0	86.0	1.1
	24		145.0	175.0	175.0	190.0	145.0	160.0	145.0	210.0	130.0	76.0
	30		40.0	65.0	70.0	110.0	91.0	91.0	76.0	48.0	52.5	28.0
A-0-A	3		1.4	1.9	2.2	27.0	1.2	22.0	11.8	.8	1.9	.7
	6		29.0	36.0	36.0	75.0	3.8	36.0	29.0	.7	1.9	.7
	12		105.0	125.0	170.0	155.0	105.0	170.0	170.0	55.0	62.0	.8
0-A-0	3		3.0	3.0	1.9	67.0	1.1	46.0	1.7	.7	11.8	.7
	6		43.0	43.0	53.0	75.0	10.3	75.0	88.0	.7	2.7	.6
	12		96.0	105.0	125.0	125.0	105.0	115.0	140.0	62.0	62.0	.8

*A-0-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

** Blocks too dry to read June 20 to July 17.

TABLE 2 (Continued).

Seeding*	Depth in Inches	Thousands of ohms										
		August 6	8	10	12	14	16	18	20	23	25	27
0-0-0	3	.7	.7	.8	1.2	1.3	5.0	33.0	5.0	1.0	.8	.9
	6	.6	.6	.7	.7	.8	1.9	8.3	8.3	1.1	1.1	1.0
	12	.5	.5	.6	.6	.6	.9	1.7	3.5	1.7	1.7	1.5
	24	1.0	.9	1.0	.9	1.0	1.1	1.6	1.6	2.2	2.[illegible]	2.3
	30	1.3	1.4	1.4	1.5	1.4	1.6	1.6	1.9	1.9	1.9	1.9
A-A-A	3	.8	1.0	2.2	8.3	11.8	46.0	67.0	1.6	.8	.9	16.5
	6	.6	.7	.8	5.5	13.5	36.0	64.0	29.0	3.8	2.2	6.7
	12	.6	.6	.6	1.1	2.2	27.0	86.0	69.0	47.0	33.0	40.0
	24	3.8	1.6	1.6	1.8	2.2	3.8	12.5	20.0	16.0	16.0	24.0
	30	10.0	3.8	4.7	16.0	7.6	20.0	36.0	12.5	3.4	3.4	6.0
A-0-A	3	.7	.7	1.2	3.0	8.3	33.0	59.0	8.3	1.0	.9	2.2
	6	.7	.7	.8	1.4	3.2	18.0	43.0	18.0	2.7	1.4	1.9
	12	.6	.6	.6	.8	1.9	40.0	78.0	78.0	40.0	27.0	27.0
0-A-0	3	.7	.8	1.5	8.3	5.0	40.0	52.0	1.2	.7	.7	1.6
	6	.6	.7	.9	4.6	10.3	29.0	53.0	36.0	2.7	1.3	1.9
	12	.6	.6	.7	1.1	2.6	27.0	96.0	55.0	40.0	21.5	27.0

*A-0-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 2 (Continued).

Seeding*	Depth in Inches	Thousands of ohms: August 29	30	September 2	4	6	8	10	12	14	16	18	20
O-O-O	3	3.0	1.1	1.2	8.3	33.0	5.0	.9	.7	.7	.8	1.3	16.5
	6	1.6	1.1	1.4	3.8	8.3	8.3	1.1	.8	.7	.7	.8	1.3
	12	1.7	5.5	5.5	13.0	21.5	27.0	3.5	.7	.7	.7	.7	.9
	24	4.7	6.0	10.0	44.0	24.0	32.0	40.0	20.0	4.7	3.4	4.7	6.0
	30	2.3	2.6	3.4	4.7	6.0	7.6	10.0	7.6	7.6	6.0	7.6	7.6
A-A-A	3	46.0	1.5	59.0	82.0	92.0	22.0	1.0	1.0	1.0	2.2	52.0	67.0
	6	43.0	29.0	75.0	102.0	75.0	75.0	1.0	.6	.7	1.0	10.3	64.0
	12	78.0	96.0	115.0	140.0	86.0	96.0	69.0	1.3	1.2	1.4	21.5	96.0
	24	36.0	58.0	70.0	84.0	130.0	76.0	84.0	58.0	65.0	58.0	65.0	91.0
	30	40.0	32.0	40.0	84.0	120.0	76.0	28.0	20.0	16.0	20.0	32.0	100.0
A-O-A	3	40.0	3.0	22.0	74.0	103.0	5.0	1.0	.7	.8	1.3	16.5	46.0
	6	13.5	8.3	22.5	53.0	117.0	64.0	1.4	.7	.7	.9	1.6	8.3
	12	47.0	125.0	140.0	155.0	200.0	78.0	86.0	1.5	1.4	1.7	27.0	96.0
O-A-O	3	46.0	1.0	2.2	59.0	82.0	11.8	.8	.7	.8	1.2	46.0	59.0
	6	10.3	18.0	36.0	53.0	75.0	53.0	1.1	.7	.7	.9	5.5	36.0
	12	40.0	62.0	105.0	115.0	96.0	105.0	62.0	1.1	1.0	1.3	9.0	105.0

*A-O-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 3. Moisture determinations in ohms resistance at various soil depths as influenced by pure stands and alternate spacing of alfalfa and orchard grass in rows spaced six inches. (Partitions)

Experiment C

Seed-* ing	Depth in Inches	Thousands of ohms										
		April 21	23	25	27	29	May 1	3	5	8	10	12
	3	5.0	46.0	128.0	205.0	255.0	385.0	420.0	74.0	11.8	103.0	255.0
	6	1.6	10.3	64.0	165.0	205.0	310.0	380.0	185.0	133.0	150.0	205.0
O-O-O	12	.8	1.4	2.6	69.0	115.0	240.0	325.0	240.0	140.0	125.0	200.0
	24	.8	.9	.9	1.1	1.6	2.3	10.0	44.0	44.0	58.0	48.0
	3	1.4	27.0	74.0	230.0	285.0	385.0	420.0	74.0	22.0	46.0	128.0
	6	1.9	13.5	310.0	355.0	700.0	545.0	545.0	185.0	53.0	150.0	290.0
A-A-A	12	2.6	17.5	69.0	375.0	280.0	430.0	460.0	215.0	215.0	215.0	215.0
	24	4.7	16.0	58.0	305.0	210.0	360.0	360.0	190.0	120.0	160.0	190.0
	3	3.0	40.0	92.0	255.0	285.0	420.0	385.0	59.0	11.8	74.0	144.0
	6	2.7	13.5	64.0	250.0	310.0	450.0	355.0	150.0	133.0	165.0	230.0
A-O-A	12	1.1	2.2	9.0	78.0	86.0	260.0	325.0	170.0	170.0	170.0	170.0
	24	1.0	1.0	1.4	2.9	20.0	36.0	91.0	91.0	70.0	84.0	130.0
	3	1.5	52.0	67.0	117.0	255.0	255.0	255.0	46.0	11.8	74.0	172.0
	6	2.7	18.0	75.0	290.0	230.0	330.0	355.0	165.0	150.0	230.0	290.0
O-A-O	12	1.9	40.0	47.0	105.0	140.0	300.0	280.0	215.0	185.0	200.0	240.0
	24	2.0	7.6	24.0	65.0	76.0	130.0	130.0	120.0	145.0	120.0	120.0

*A-O-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 3 (Continued).

Seed-* ing	Depth in Inches	Thousands of ohms										
		May			June							
		17	20	23	5	7	10	12	14	16	18	20
	3	92.0	128.0	285.0	.7	1.3	1.0	1.7	67.0	92.0	172.0	172.0
	6	150.0	270.0	290.0	1.1	2.2	2.2	3.2	29.0	75.0	150.0	165.0
0-0-0	12	200.0	260.0	280.0	62.0	69.0	62.0	62.0	62.0	78.0	125.0	155.0
	24	52.5	84.0	130.0	65.0	70.0	65.0	48.0	52.5	44.0	65.0	130.0
	3	128.0	205.0	255.0	1.3	117.0	16.5	92.0	128.0	103.0	172.0	172.0
	6	270.0	270.0	310.0	13.5	133.0	64.0	117.0	185.0	165.0	205.0	185.0
A-A-A	12	215.0	240.0	260.0	105.0	170.0	69.0	115.0	170.0	105.0	185.0	155.0
	24	330.0	280.0	305.0	120.0	160.0	76.0	145.0	175.0	110.0	175.0	175.0
	3	144.0	172.0	205.0	.7	3.0	1.1	16.5	117.0	144.0	205.0	172.0
	6	185.0	205.0	270.0	1.9	5.5	5.5	22.5	88.0	117.0	165.0	150.0
A-0-A	12	140.0	325.0	200.0	62.0	78.0	55.0	69.0	96.0	105.0	140.0	125.0
	24	91.0	120.0	160.0	76.0	100.0	44.0	70.0	91.0	84.0	110.0	100.0
	3	144.0	182.0	205.0	1.7	82.0	11.8	92.0	117.0	117.0	144.0	128.0
	6	150.0	205.0	230.0	43.0	117.0	75.0	102.0	133.0	102.0	133.0	133.0
0-A-0	12	185.0	185.0	215.0	62.0	125.0	78.0	86.0	125.0	105.0	125.0	125.0
	24	110.0	130.0	175.0	65.0	110.0	65.0	76.0	100.0	100.0	110.0	100.0

*A-0-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 3 (Continued).

Seed-* ing	Depth in Inches	July **	17	19	21	23	25	27	29	31	August 2	4
			Thousands of ohms									
	3		1.0	.8	.7	1.0	.7	1.2	1.0	.7	.8	.7
	6		22.5	22.5	13.5	18.0	.6	.8	.7	.6	.6	.5
0-0-0	12		155.0	78.0	115.0	115.0	105.0	62.0	69.0	.7	.7	.5
	24		145.0	91.0	145.0	160.0	110.0	120.0	100.0	84.0	76.0	.8
	3		.7	1.6	1.6	67.0	1.1	74.0	1.3	.7	1.9	.7
	6		10.3	36.0	43.0	102.0	1.1	53.0	8.3	.7	2.7	.6
A-A-A	12		86.0	105.0	115.0	125.0	86.0	140.0	140.0	9.0	62.0	.5
	24		130.0	145.0	175.0	190.0	120.0	175.0	160.0	160.0	190.0	76.0
	3		.8	1.2	1.0	5.0	.7	1.7	1.0	.7	1.0	.7
	6		10.3	18.0	13.5	13.5	.7	1.4	2.7	.6	.9	.5
A-0-A	12		62.0	69.0	78.0	86.0	55.0	55.0	55.0	1.7	9.0	.6
	24		91.0	84.0	100.0	110.0	70.0	76.0	84.0	65.0	91.0	52.5
	3		.8	5.0	11.8	103.0	1.2	82.0	1.9	.7	8.3	.7
	6		43.0	43.0	64.0	88.0	8.3	53.0	13.5	.6	4.6	.5
0-A-0	12		96.0	78.0	105.0	115.0	105.0	115.0	86.0	47.0	40.0	.6
	24		84.0	84.0	91.0	100.0	100.0	84.0	76.0	65.0	76.0	4.7

*A-0-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

**Blocks too dry to read June 20 to July 17.

TABLE 3 (Continued).

Seeding*	Depth in Inches	Thousands of ohms: August 6	8	10	12	14	16	18	20	23	25	27
O-O-O	3	.7	.7	.7	.8	.8	1.4	11.8	1.2	.7	.7	.8
	6	.5	.5	.6	.7	.7	1.1	2.7	1.1	.7	.6	.6
	12	.5	.5	.5	.6	.6	.8	1.1	.9	.7	.6	.7
	24	.6	.6	.6	.6	.7	.7	.7	.6	.7	.6	.6
A-A-A	3	.7	.8	3.0	16.5	27.0	59.0	82.0	1.6	.8	.9	11.8
	6	.6	.6	1.1	13.5	29.0	64.0	102.0	10.3	.9	.9	4.6
	12	.5	.5	.6	1.9	17.5	62.0	105.0	86.0	62.0	47.0	55.0
	24	1.2	1.0	.8	1.6	2.6	32.0	16.0	76.0	58.0	52.5	58.0
A-O-A	3	.7	.7	.7	.7	.7	.9	1.9	.8	.7	.7	.7
	6	.6	.6	.6	.6	.6	.7	.9	.7	.6	.6	.6
	12	.5	.5	.5	.6	.6	.6	.7	.8	.6	.6	.6
	24	.6	.6	.6	.6	.6	.6	.6	.7	.6	.7	.7
O-A-O	3	.7	1.0	3.0	27.0	40.0	52.0	92.0	1.1	.7	.8	3.0
	6	.5	.6	1.6	29.0	43.0	43.0	64.0	10.3	.7	.7	2.7
	12	.5	.5	.7	2.2	13.0	47.0	69.0	62.0	47.0	33.0	40.0
	24	.8	.7	.7	1.0	1.8	12.5	52.5	44.0	40.0	36.0	36.0

*A-O-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 3 (Continued).

Seed-* ing	Depth in Inches	Thousands of ohms											
		August		September									
		29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	3	1.9	.8	.8	1.2	3.0	1.1	.8	.7	.7	.8	1.0	1.7
	6	.6	.6	.7	.7	1.0	1.1	.7	.6	.6	.6	.7	.7
	12	.7	.7	.7	.8	.8	.8	.6	.6	.6	.6	.6	.6
	24	.6	.6	.6	.8	.8	.9	.6	.6	.6	.6	.6	.6
A-A-A	3	46.0	1.4	52.0	103.0	128.0	40.0	.9	.7	.8	1.7	16.5	74.0
	6	36.0	10.3	53.0	102.0	117.0	75.0	1.1	.6	.6	1.1	22.5	88.0
	12	47.0	69.0	125.0	115.0	125.0	96.0	9.0	.8	.9	1.5	47.0	96.0
	24	48.0	84.0	120.0	110.0	84.0	100.0	100.0	100.0	84.0	84.0	84.0	120.0
A-0-A	3	1.1	.7	.7	1.0	1.7	.8	.7	.7	.7	.7	.7	.9
	6	.6	.6	.6	.7	.7	.7	.6	.6	.6	.6	.6	.6
	12	.5	.6	.6	.7	.7	.7	.5	.5	.5	.5	.5	.5
	24	.6	.8	1.0	1.2	1.3	1.8	1.3	.6	.6	.6	.6	.6
0-A-0	3	40.0	.9	27.0	103.0	128.0	22.0	.8	.7	1.1	16.5	74.0	103.0
	6	29.0	5.5	36.0	64.0	64.0	53.0	.6	.6	.7	3.2	43.0	75.0
	12	33.0	47.0	86.0	86.0	86.0	69.0	27.0	.7	.8	1.7	33.0	69.0
	24	32.0	44.0	70.0	76.0	84.0	58.0	52.5	44.0	44.0	40.0	52.5	58.0

*A-0-A treatment, for example, denotes orchard grass row between two alfalfa rows. Moisture blocks were placed under center row of species noted.

TABLE 4. Per cent soil moisture at indicated depths as influenced by pure stands and alternate spacing of alfalfa and orchard grass in rows spaced six inches. (No Partitions)

Three-inch depth

Experiment C

Permanent wilting percentage = 5.4%

Seed-*		April									May		
ing	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	9.6	8.6	8.1	7.7	7.2	7.0	6.7	7.8	8.5	7.7	6.9	7.0	7.3	6.8
A-A-A	9.7	8.9	8.2	7.9	7.5	7.0	6.8	7.5	8.5	7.8	7.3	7.4	7.1	6.6
A-0-A	9.4	8.1	7.4	6.9	6.9	6.5	6.6	7.9	8.2	7.8	7.3	7.3	7.0	6.8
0-A-0	9.1	8.2	6.8	6.7	6.8	6.4	6.4	7.6	8.0	7.3	6.8	6.9	6.9	6.8
		June										July		
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	10.8	9.1	9.8	8.6	7.9	8.0	7.4	7.4		9.6	9.7	9.8	9.3	10.1
A-A-A	8.9	7.2	8.5	7.6	7.8	7.2	7.5	7.0		10.0	8.8	8.9	7.7	9.9
A-0-A	9.8	8.1	8.6	8.0	7.5	7.8	7.4	7.3		9.8	9.4	9.3	8.6	10.1
0-A-0	9.3	7.6	8.2	7.8	7.3	7.8	7.3	6.9		9.2	9.2	9.4	8.0	10.2
		July										August		
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	9.3	9.2	10.4	9.9	11.3	11.6	11.5	10.9	10.1	9.9	9.1	8.5	9.1	10.5
A-A-A	7.8	9.6	10.7	8.8	11.0	10.8	10.5	9.3	9.0	8.9	8.3	8.0	9.6	10.8
A-0-A	8.7	8.9	10.9	9.4	11.5	11.5	11.3	10.0	9.2	9.0	8.5	8.1	9.0	10.4
0-A-0	8.3	9.5	11.2	8.9	11.5	11.5	11.0	9.7	9.0	9.1	8.4	8.2	10.1	11.3
		August										September		
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	11.1	10.6	9.2	10.2	10.1	9.0	8.5	9.1	10.6	11.4	11.3	10.9	9.9	8.8
A-A-A	10.6	8.8	8.3	9.7	8.1	7.8	7.7	8.7	10.5	10.5	10.3	9.3	8.2	8.0
A-0-A	10.7	9.3	8.4	9.2	8.7	7.9	7.6	9.1	10.4	11.2	11.0	9.9	8.8	8.3
0-A-0	11.3	9.6	8.3	10.5	9.3	8.1	7.8	8.9	11.1	11.2	10.9	10.0	8.3	8.1

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 4 (Continued).

Six-inch depth

Permanent wilting percentage = 8.2%

Seed-*		April									May			
ing	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	13.8	12.9	12.2	11.8	11.2	10.5	10.4	10.9	11.4	11.3	10.8	11.2	11.1	10.7
A-A-A	13.4	12.6	11.9	11.7	10.9	10.8	10.5	11.4	11.8	11.6	11.3	10.8	10.9	10.8
A-0-A	13.6	12.5	11.7	11.4	11.0	10.4	10.3	11.1	11.3	11.0	10.8	10.8	11.0	10.8
0-A-0	13.4	12.5	11.9	11.0	11.1	10.6	10.5	11.3	11.1	11.1	10.8	11.0	11.1	10.9
		June										July		
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	13.2	12.6	12.8	12.3	11.8	11.7	11.4	11.3		12.4	12.5	12.6	12.4	13.1
A-A-A	12.5	12.2	12.1	11.6	11.6	11.8	11.4	11.5		12.3	12.0	11.9	11.7	13.2
A-0-A	12.7	11.8	12.1	11.7	11.3	11.7	11.2	11.4		12.4	12.3	12.3	11.9	13.3
0-A-0	12.2	11.7	12.1	11.8	11.4	11.8	11.5	11.4		12.2	12.2	12.1	11.9	12.8
		July										August		
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	12.8	12.2	14.1	14.1	15.2	15.4	15.4	15.2	14.9	14.6	13.7	12.9	12.9	14.1
A-A-A	11.7	12.2	14.9	13.2	15.7	15.7	15.3	14.6	13.1	12.7	12.3	12.0	12.4	13.3
A-0-A	12.3	12.4	14.8	13.7	15.3	15.2	15.2	14.7	13.9	13.4	12.6	12.2	12.6	13.5
0-A-0	11.9	11.8	14.9	13.5	15.6	15.5	15.3	14.4	13.2	12.8	12.4	12.1	12.3	13.5
		August										September		
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	14.2	14.3	13.8	14.1	13.9	13.3	12.9	12.9	14.2	14.7	14.8	14.8	14.6	14.0
A-A-A	13.6	13.0	12.2	12.4	11.9	11.7	11.9	11.9	14.3	15.4	15.1	14.3	12.8	12.0
A-0-A	13.9	13.7	12.7	12.9	12.5	12.1	11.6	12.0	13.9	14.9	14.9	14.5	13.8	12.9
0-A-0	14.0	13.7	12.8	12.6	12.3	12.1	11.9	12.1	14.2	15.3	15.0	14.4	13.1	12.3

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 4 (Continued).

<u>Twelve-inch depth</u>

Permanent wilting percentage = 14.9%

Seed-* ing	April 21	23	25	27	29	May 1	3	5	8	10	12	17	20	23
0-0-0	19.5	19.0	18.3	17.7	16.7	16.5	16.1	16.4	16.5	16.5	16.4	16.7	16.4	16.0
A-A-A	18.4	17.8	17.0	16.6	16.6	15.6	15.5	16.1	16.1	16.1	16.1	15.9	16.1	15.8
A-0-A	18.9	17.4	17.2	16.6	16.4	15.3	15.2	16.2	16.2	16.2	16.2	15.9	16.4	16.0
0-A-0	18.7	17.7	17.5	17.1	15.7	15.4	15.5	16.2	16.1	16.2	16.2	16.2	15.8	15.7
	June 5	7	10	12	14	16	18	20	**	July 17	19	21	23	25
0-0-0	17.1	17.0	17.5	17.2	16.9	17.2	16.7	16.6		17.2	17.1	16.9	16.7	17.3
A-A-A	16.4	16.1	16.8	16.5	16.3	16.9	16.3	16.5		16.6	16.6	16.6	16.4	16.8
A-0-A	16.6	16.5	17.4	17.1	16.5	17.0	16.2	16.6		17.0	16.8	16.5	16.6	17.0
0-A-0	17.0	16.6	17.3	17.0	16.2	17.0	16.4	16.6		17.1	17.0	16.8	16.8	17.0
	July 27	29	31	August 2	4	6	8	10	12	14	16	18	20	23
0-0-0	17.3	17.3	17.9	17.8	21.1	21.8	21.8	21.6	21.3	20.9	19.9	19.0	18.6	19.0
A-A-A	16.7	17.2	17.1	17.2	19.6	21.3	21.3	20.9	19.6	18.8	18.0	17.2	17.4	17.7
A-0-A	16.5	16.5	17.6	17.5	20.3	21.3	21.3	20.9	20.0	18.9	17.8	17.3	17.3	17.8
0-A-0	16.9	16.7	17.5	17.5	20.3	21.0	21.0	20.8	19.6	18.7	18.0	17.1	18.5	17.8
	August 25	27	29	30	September 2	4	6	8	10	12	14	16	18	20
0-0-0	19.0	19.1	19.0	18.5	18.5	18.3	18.1	18.0	18.6	20.5	20.7	20.7	20.4	19.9
A-A-A	17.9	17.8	17.3	17.1	16.9	16.7	17.2	17.1	17.4	19.3	19.4	19.2	18.1	17.1
A-0-A	18.0	18.0	17.7	16.8	16.7	16.6	16.3	17.3	17.2	19.1	19.2	19.0	18.0	17.1
0-A-0	18.1	18.0	17.8	17.5	17.0	16.9	17.1	17.0	17.5	19.6	19.7	19.3	18.4	17.0

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 4 (Continued).

Twenty-four inch depth

Permanent wilting percentage = 20.1%

Seed-*		April										May		
ing	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	26.6	26.4	26.0	25.4	25.0	24.7	23.7	23.3	23.3	23.3	23.7	23.2	22.7	22.3
A-A-A	25.3	24.9	23.9	23.2	22.2	21.7	21.4	21.8	21.9	21.8	21.5	21.8	21.9	21.7
		June										July		
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	22.9	22.6	23.0	22.8	22.7	22.9	22.6	22.4		22.8	22.6	22.4	22.4	22.8
A-A-A	22.2	21.9	22.6	22.4	22.3	22.9	22.3	22.2		22.4	22.2	22.2	22.1	22.4
		July										August		
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	22.7	22.8	22.7	22.5	23.3	26.8	27.0	26.9	27.0	26.9	26.6	26.0	25.9	25.5
A-A-A	22.3	22.4	22.0	22.5	23.1	25.0	25.9	26.0	25.8	25.5	25.0	24.5	24.3	24.4
		August										September		
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	25.5	25.4	24.9	24.8	24.6	23.7	24.2	24.0	23.8	24.3	24.9	25.1	24.9	24.8
A-A-A	24.4	24.2	23.9	23.4	23.2	23.0	22.5	23.1	23.0	23.4	23.3	23.4	23.3	22.9

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 4 (Continued).

<u>Thirty-inch depth</u>

Permanent wilting percentage = 20.1%

Seed-* ing	April					May								
	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	26.8	26.5	26.7	26.0	25.9	25.3	24.9	24.3	24.5	24.4	24.0	24.6	23.6	23.1
A-A-A	25.3	25.0	24.4	24.1	23.9	23.2	22.7	23.2	23.3	23.5	23.4	22.1	22.4	21.8
	June									July				
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	23.9	23.9	23.8	23.9	23.8	23.8	23.5	22.9		22.9	23.0	23.0	23.0	23.1
A-A-A	23.9	22.7	23.2	22.8	22.8	23.5	23.1	22.4		23.8	23.3	23.2	22.7	22.9
	July			August										
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	23.2	23.1	23.4	23.1	23.7	26.3	26.2	26.2	26.1	26.2	26.0	25.9	25.7	25.7
A-A-A	22.9	23.1	23.6	23.5	24.1	24.6	25.0	24.9	24.4	24.7	24.3	23.9	24.5	25.1
	August				September									
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	25.7	25.7	25.4	25.3	25.1	24.9	24.8	24.7	24.6	24.7	24.7	24.8	24.7	24.7
A-A-A	25.1	24.8	23.8	24.0	23.8	23.0	22.6	23.1	24.1	24.3	24.4	24.3	24.0	22.8

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 5. Per cent soil moisture at indicated depths as influenced by pure stands and alternate spacing of alfalfa and orchard grass in rows spaced six inches. (Partitions)

Experiment C

Three-inch depth

Permanent wilting percentage = 5.4%

Seed-* ing	April					May								
	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	9.1	8.3	7.4	7.0	6.8	6.4	6.3	7.9	8.9	7.6	6.8	7.7	7.4	6.7
A-A-A	9.8	8.6	7.9	6.9	6.7	6.4	6.3	7.9	8.7	8.3	7.4	7.4	7.0	6.8
A-0-A	9.2	8.4	7.7	6.8	6.7	6.3	6.4	8.1	8.9	7.9	7.3	7.3	7.2	7.0
0-A-0	9.7	8.2	8.0	7.5	6.8	6.8	6.8	8.3	8.9	7.9	7.2	7.3	7.1	7.0
	June									July				
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	11.5	9.9	10.4	9.5	8.0	7.7	7.2	7.2		10.3	11.1	11.3	10.3	11.7
A-A-A	9.9	7.5	8.8	7.7	7.4	7.6	7.2	7.2		11.3	9.6	9.6	8.0	10.2
A-0-A	11.4	9.2	10.2	8.8	7.5	7.3	7.0	7.2		10.9	10.0	10.3	9.1	11.6
0-A-0	9.5	7.8	8.9	7.7	7.5	7.5	7.3	7.4		11.0	9.1	8.9	7.6	10.0
	July			August										
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	10.1	10.4	11.9	11.0	12.0	12.0	12.0	11.2	10.8	11.0	9.8	8.9	10.1	11.8
A-A-A	7.9	9.9	11.4	9.4	11.7	11.6	10.8	9.2	8.8	8.6	8.1	7.8	9.6	10.8
A-0-A	9.8	10.5	11.4	10.4	11.8	11.8	11.8	11.5	11.4	11.4	10.6	9.4	10.8	12.0
0-A-0	7.8	9.4	11.4	9.0	11.8	11.6	10.4	9.2	8.6	8.4	8.2	7.7	10.2	11.2
	August				September									
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	11.5	11.1	9.4	11.0	10.8	10.1	9.2	10.2	11.1	11.8	11.6	11.0	10.4	9.5
A-A-A	10.7	8.9	8.3	9.8	8.2	7.6	7.4	8.4	10.6	11.2	10.8	9.5	8.8	7.9
A-0-A	12.0	11.6	10.2	11.8	11.4	10.3	9.5	11.0	11.5	11.6	11.4	11.4	11.2	10.7
0-A-0	11.1	9.2	8.4	10.6	8.6	7.6	7.4	8.7	10.8	11.2	10.2	8.8	7.9	7.6

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 5 (Continued).

<u>Six-inch depth</u>

Permanent wilting percentage = 8.2%

Seed-*														
		April										May		
ing	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	13.8	12.8	12.0	11.3	11.1	10.6	10.3	11.2	11.5	11.4	11.1	11.4	10.8	10.7
A-A-A	13.7	12.7	10.6	10.4	9.0	9.6	9.6	11.2	12.1	11.4	10.7	10.8	10.8	10.6
A-0-A	13.5	12.7	12.0	10.9	10.6	10.0	10.4	11.4	11.5	11.3	11.0	11.2	11.1	10.8
0-A-0	13.5	12.6	11.9	10.7	11.0	10.5	10.4	11.3	11.4	11.0	10.7	11.4	11.1	11.0
		June										July		
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	14.1	13.6	13.6	13.4	12.4	11.9	11.4	11.3		12.5	12.5	12.7	12.6	15.8
A-A-A	12.7	11.5	12.0	11.6	11.2	11.3	11.1	11.2		12.8	12.3	12.2	11.7	14.1
A-0-A	13.7	13.1	13.1	12.5	11.8	11.6	11.3	11.4		12.8	12.6	12.7	12.7	15.1
0-A-0	12.2	11.6	11.9	11.7	11.5	11.7	11.5	11.5		12.2	12.2	12.0	11.8	12.9
		July										August		
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	14.6	15.0	16.2	15.6	16.9	16.6	16.6	16.0	15.3	15.0	14.1	13.5	14.1	15.2
A-A-A	12.1	12.9	15.0	13.5	16.2	16.0	15.7	14.2	12.7	12.4	12.0	11.7	12.8	14.4
A-0-A	13.9	13.5	15.5	14.4	16.6	16.2	16.2	16.0	15.9	15.9	14.9	14.4	14.8	16.4
0-A-0	12.1	12.7	15.5	13.2	16.8	16.5	15.5	13.8	12.4	12.2	12.2	12.0	12.8	14.9
		August										September		
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	15.5	15.6	15.5	15.6	15.3	15.0	14.3	14.2	15.3	15.8	15.8	15.7	15.3	14.9
A-A-A	14.5	13.2	12.3	12.8	12.1	11.7	11.6	11.9	14.2	15.7	15.4	14.1	12.5	11.8
A-0-A	16.3	16.4	15.6	16.2	15.6	15.3	15.2	14.9	16.0	16.0	15.9	15.8	15.6	15.8
0-A-0	15.0	13.5	12.4	13.1	12.3	12.0	12.0	12.1	15.4	15.9	15.0	13.4	12.2	11.9

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.

TABLE 5 (Continued).

Twelve-inch depth

Permanent wilting percentage = 14.9%

Seed-*ing	April 21	23	25	27	29	May 1	3	5	8	10	12	17	20	23
0-0-0	20.1	19.2	18.7	17.4	16.9	16.1	15.7	16.1	16.7	16.8	16.3	16.3	16.0	15.9
A-A-A	18.7	18.2	17.4	15.5	15.9	15.3	15.2	16.2	16.2	16.2	16.2	16.2	16.1	16.0
A-0-A	19.6	18.8	18.4	17.3	17.2	16.0	15.7	16.5	16.5	16.5	16.5	16.7	15.7	16.3
0-A-0	18.9	17.8	17.7	17.0	16.7	15.8	15.9	16.2	16.4	16.3	16.1	16.4	16.4	16.2
	June 5	7	10	12	14	16	18	20	**	July 17	19	21	23	25
0-0-0	17.5	17.4	17.5	17.5	17.5	17.3	16.8	16.6		16.6	17.3	16.9	16.9	17.0
A-A-A	17.0	16.5	17.4	16.9	16.5	17.0	16.4	16.6		17.2	17.0	16.9	16.8	17.2
A-0-A	17.5	17.3	17.6	17.4	17.1	17.0	16.7	16.8		17.5	17.4	17.3	17.2	17.6
0-A-0	17.5	16.8	17.3	17.2	16.8	17.0	16.8	16.8		17.1	17.3	17.0	16.9	17.0
	July 27	29	31	August 2	4	6	8	10	12	14	16	18	20	23
0-0-0	17.5	17.4	20.6	20.5	22.0	22.0	22.0	21.9	21.6	21.6	20.2	19.6	19.9	20.5
A-A-A	16.7	16.7	18.4	17.5	21.8	22.0	21.8	21.2	18.9	18.2	17.5	17.0	17.2	17.5
A-0-A	17.6	17.6	19.0	18.4	21.2	22.0	21.7	21.6	21.6	21.5	21.3	20.4	20.2	21.2
0-A-0	16.9	17.2	17.7	17.8	21.6	21.8	21.7	20.6	18.8	18.3	17.7	17.4	17.5	17.7
	August 25	27	29	30	September 2	4	6	8	10	12	14	16	18	20
0-0-0	21.0	20.5	20.4	20.6	20.6	20.2	20.3	20.1	20.9	21.1	21.6	21.6	21.5	21.4
A-A-A	17.7	17.6	17.7	17.4	16.8	16.9	16.8	17.1	18.4	20.0	19.9	19.1	17.7	17.1
A-0-A	21.4	21.5	21.7	21.4	20.9	20.5	20.7	20.5	21.8	21.8	21.8	21.8	21.8	21.8
0-A-0	17.9	17.8	17.9	17.7	17.2	17.2	17.2	17.4	18.0	20.5	20.0	19.0	17.9	17.4

*Moisture blocks placed directly under center row of species indicated

**Blocks too dry to read June 20 to July 17.

TABLE 5 (Continued).

Twenty-four inch depth

Permanent wilting percentage = 20.1%

Seed-* ing	April											May		
	21	23	25	27	29	1	3	5	8	10	12	17	20	23
0-0-0	27.3	27.1	27.1	26.7	26.0	25.4	24.6	23.7	23.7	23.4	23.6	23.5	23.0	22.5
A-A-A	24.9	24.4	23.4	21.6	22.0	21.4	21.4	22.1	22.6	22.3	22.1	21.5	21.7	21.6
A-0-A	26.9	26.8	26.2	25.2	24.3	23.9	22.9	22.9	23.2	23.0	22.5	22.9	22.6	22.3
0-A-0	25.6	24.7	24.2	23.3	23.1	22.5	22.5	22.6	22.4	22.6	22.6	22.7	22.5	22.2
	June											July		
	5	7	10	12	14	16	18	20	**	17	19	21	23	25
0-0-0	23.3	23.2	23.3	23.6	23.5	23.7	23.3	22.5		22.4	22.9	22.4	22.3	22.7
A-A-A	22.6	22.3	23.1	22.4	22.2	22.7	22.2	22.2		22.5	22.4	22.2	22.1	22.6
A-0-A	23.1	22.8	23.7	23.2	22.9	23.0	22.7	22.8		22.9	23.0	22.8	22.7	23.2
0-A-0	23.3	22.7	23.3	23.1	22.8	22.8	22.7	22.8		23.0	23.0	22.9	22.8	22.8
	July											August		
	27	29	31	2	4	6	8	10	12	14	16	18	20	23
0-0-0	22.6	22.8	23.0	23.1	27.2	28.9	28.9	28.9	28.9	29.0	27.7	27.7	28.1	27.9
A-A-A	22.2	22.3	22.3	22.1	23.1	26.4	26.8	27.4	26.0	25.3	24.0	24.4	23.1	23.4
A-0-A	23.1	23.0	23.3	22.9	23.5	28.2	28.4	28.5	28.8	28.8	28.6	28.2	27.2	28.0
0-A-0	23.0	23.1	23.3	23.1	24.9	27.3	27.7	27.8	26.9	25.8	24.5	23.5	23.7	23.8
	August											September		
	25	27	29	30	2	4	6	8	10	12	14	16	18	20
0-0-0	28.7	28.7	28.1	28.5	28.1	27.3	27.4	27.0	28.0	28.8	28.8	28.9	28.8	28.8
A-A-A	23.5	23.4	23.6	23.0	22.6	22.7	23.0	22.8	22.8	22.8	23.0	23.0	23.0	22.6
A-0-A	27.8	27.7	28.3	27.4	26.8	26.5	26.3	25.8	26.3	28.2	28.3	28.5	28.5	28.5
0-A-0	23.9	23.9	24.0	23.7	23.2	23.1	23.0	23.4	23.5	23.7	23.8	23.8	23.5	23.4

*Moisture blocks placed directly under center row of species indicated.

**Blocks too dry to read June 20 to July 17.